THE

JOURNAL

OF THE

FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

PUBLISHED BY

THE INSTITUTE,

Under the Direction of the Committee on Publication.

Vol. CXVII.—Nos. 697—702.

THIRD SERIES.

VOL. LXXXVII.—JANUARY TO JUNE, 1884.

PHILADELPHIA:

FRANKLIN INSTITUTE, No. 15 SOUTH SEVENTH STREET

1884.

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXVII.

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JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVII. JANUARY, 1884. No. 1.

NOTE ON THE LOSSES PER HORSE-POWER PER HOUR BY CONDENSATION OF THE STEAM IN PIPES AND CYLINDERS OF STEAM ENGINES.

BY WILLIAM DENNIS MARKS,

Whitney Professor Dynamical Engineering, University of Pennsylvania.

In this JOURNAL OF THE FRANKLIN INSTITUTE for December, 1883, the writer has published a paper on "The Cheapest Point of Cut-off," in which he has endeavored to show, in a practically useful way, that the greatest economy in the use of steam, and consequently the greatest saving in money, is effected by making the point of cut-off

$$c = \frac{B\left(1 - b\left[1 - \text{nat. log.}\,\frac{b}{k}\right]\right)}{P_b} + k - b\,\frac{B}{P_b}\,\text{nat. log.}\,\frac{1}{c},$$

within certain limitations as to number of expansions in which

B = the absolute back pressure in lbs. per sq. inch with exhaust open.

P_b = the absolute initial pressure in lbs. per sq. inch.

k = the fraction of the volume of steam cylinder equal to clearance.

b = the fraction of the volume of steam cylinder at which compression begins being measured from the opposite end to c.

What is needed to render this rule practically accurate within the widest range, is to establish the ratio which exists between the steam

furnished by the boiler and that recorded by the indicator diagram, under all the various conditions as to initial and back pressures, and points of cut-off used.

The quantity of steam recorded by the diagram, if deduced by the usual rule is simply the amount of steam remaining as vapor in the steam cylinder after the steam has done its work, and with all its conveyed heat it is immediately thrown away through the exhaust port.

The diagram makes a record of the steam heat converted into work, in foot lbs. Of the steam heat absorbed by the pipes and cylinder walls it makes no record.

It is true, nevertheless, that the usual rule (which is to divide 859375 by the mean effective pressure, multiplied by the specific volume of the steam for the terminal pressure); is of value for the quantity of heat furnished by the boiler being the same, and the condensation being the same, that engine which shows the least rate of steam per horse power per hour has proved most economical, since it has allowed the smallest quantity of steam to pass through the exhaust port unutilized. This quantity may be corrected for compression by inserting the term $1 - \frac{bB}{P_t}$, $P_t =$ absolute terminal pressure.

Another rule deduced by the writer is

$$\text{Weight of steam per HP per hour} = \frac{859375\left(e - b\frac{B}{P_b}\right)}{PS}$$

in which $P =$ the mean effective pressure per sq. inch, and $S =$ the specific volume of the steam for the initial pressure. This rule would give the weight of steam per horse-power per hour actually furnished in the form of vapor, to propel the engine piston, but does not record the steam lost by condensation in pipes and steam cylinder, up to point of cut-off and assumes that the pressure is not lost by throttling up to the actual point of cut-off.

It should be remembered both in the usual rule and our own, that the assumption of an isothermal expansion curve gives, practically, a nearer average of pressures so far as we can judge from the indicator diagram than any other curve, and that in our own rule since the specific volume is taken from the initial pressure, there is no error introduced in the quantity of steam per hour by reason of the terminal

pressure being assumed to vary according to Marriotte's law, thus introducing a large error, because of the great variation in the volume of steam at low terminal pressures.

The very large percentage of the steam furnished by the boiler which is lost through the exhaust in the form of vapor, will be seen from the following examples taken from the report of J. W. Hill, of the competitive tests of three engines at the first Miller's International Exhibition, Cincinnati, 1880.

All of these quantities refer to one IP per hour.

	Condensing Trial.					
	Reynolds Corliss.	Per cent.	Harris Corliss.	Per cent.	Wheelock	Per cent.
Actual steam from boilers	lbs. 20·618	....	lbs. 19·361	......	lbs. 19·475	....
Thermal value per lb	1243·84	....	1415·86	......	1301·65	......
Total British units of heat	25615·5	100·	25480·3	100·	25310·8	100·
Steam by the usual rule	14·880	72·2	13·755	71·03	13·915	71·45
Thermal value per lb	1179·07	....	1178·5	....	1177·9	......
Total British units of heat	17152·2	66·9	16208·2	63·61	[illegible]	61·62
One HP per hour in heat units	2561·8	10·0	2561·8	10·06	2561·8	10·12
Heat lost by condensation in pipes and cyl. and leakage	5928·5	23·1	6707·3	26·31	[illegible]	25·26
Net horse-power	143·19	....	145·08	......	[illegible]	....
Ind. horse-power	162·49	....	165·58	......	158·38	....

	Non-Condensing Trial.					
	Reynolds Corliss.	Per cent.	Harris Corliss.	Per cent.	Wheelock	Per cent.
Actual steam from boilers	lbs. 25,945	....	lbs. 23·467	...	lbs. 21·703	....
Thermal value per lb	1211·80	....	1255·71	...	1171·11	.....
Total British units of heat	31437·2	100·	[illegible]	100·	[illegible]	100·
Steam by the usual rule	18·896	72·82	18·019	75·5	18·671	75·73
Thermal value per lb	1181·23	..	1180·80	.	1181·25	......
Total British units of heat	22320·5	71·62	21271·[illegible]	[illegible]	[illegible]	71·
One H P per hour in heat units	2561·8	8·16	2561·8	8·54	2561·8	7·81
Heat lost by condensation in pipes and cyl. and leakage	6511·9	20·82	7185·9	[illegible]	[illegible]	21·16
Net horse-power	121·80	.....	119·74	......	123·74	......
Ind. horse-power	137·42	....	134·29	......	[illegible]	.....

The value of one HP per hour in heat units has been obtained by dividing 1,980,000 foot lbs. by 772. Other values of the heat unit laying claim to greater accuracy have been obtained, and those having any preference can of course use them.

A fair, comparative test of the skill of engine builders can only be made by assigning as work for each engine a net horse-power proportional to the volume of its cylinder (clearance included), multiplied by its number of strokes per minute.

Each engine should have the same pressure of steam of an equal thermal value. The quantity 2564·8 divided by the quantity of heat furnished to the engine in one hour will then prove the measure of its efficiency both as a means of converting heat into work, and as a machine for the transmission of power.

Corrections can be made for slight variations from the prescribed conditions, but these should be avoided as much as possible.

As a means of comparison any considerable variations from the prescribed conditions will render the experiments valueless. If, however, these conditions are fulfilled, they will enable the comparison to be made between any engines, however much they may differ in mode of construction.

Weighing the water in large tanks is the only safe method. Water meters have rendered much labor of the most painstaking kind quite valueless. This method has the great advantage of doing away with that most unreliable of instruments, the indicator, and substituting for it scales and thermometers.

Scales can be obtained of any desired degree of accuracy, as can also thermometers, by applying to the authorities at the Johns Hopkins University, Baltimore, Md., or to Yale College, New Haven, Conn.

The indicator will then be relegated to its proper place as a means of detecting gross errors of construction, and of determining average means of effective, initial and terminal pressures with relative accuracy.

It is worthy of note that the proportion of weight of actual steam to the weight of steam by the usual rule per HP per hour, does not represent the proportion of the heat furnished to the heat lost through the exhaust, since the thermal value of the steam at the terminal pressure is less than its value at initial pressure.

This can be seen from the table which shows the percentages of the

weights of water to be greater than the percentages of the heat units at boiler and terminal pressures.

The most suggestive point of the table is the approximate uniformity of the ratio of water by the indicator to the actual water evaporated for both condensing and non-condensing engines per IP per hour, its variation is within the limits of error of the best indicators.

If this ratio prove constant then will the discussion of the cheapest point of cut off, which has proved itself true within the range of Mr. Hill's experiments hold good for all conditions, but this point remains to be verified by experiment, as already set forth in a previous paper.

THE CHEAPEST POINT OF CUT-OFF.

By De Volson Wood.

It is proper to observe, that in Professor Marks analysis of this problem in the last December number of this Journal, the constant charges are assumed to be a constant fraction of the cost of steam. This, in other words, is equivalent to assuming that the constant charges *vary* with the cost of steam, a proposition involving, in general, a self-contradiction. But granting that, in the special case considered by Professor Marks, which involves a given horsepower per hour, is correctly represented by his equation (5), the result will be, independent of constant charges, but *not so for any other law.* The solution then is not general but *special;* and we may draw the inference that "the point of cheapest cut-off" is *generally* dependent upon the constant charges.

Artificial Auroras – Prof. Lenstrom, director of the Meteorological Observatory of Sodankygla, Finland, produced artificial auroras by passing a strong electric current through a copper wire, which surrounded the hill of Pietrotneturi, near Cullala. A few days afterwards he surrounded, in like manner, a space of 900 square metres on the summit of the hill Ovatnaturi. In the latter experiment he saw the cone surrounded by a yellowish light, which resembled the streamers of the aurora borealis. –*Les Mondes*, April 21, 1883. C.

THE THEORY OF TURBINES.

[ABSTRACT.]

By Robert H. Thurston.

[Am. Soc. Mechanical Engineers: November Meeting, New York, 1883.]

(Concluded from page 459.)

24. Centrifugal action and friction modify the theory of the turbine, as already indicated; the one altering, in equal amount, both the energy expended and the energy usefully applied, and the other by reducing the head, reaching and impelling the wheel. It has been seen that these quantities of work can be represented by expressions involving the velocities of current and quantities having the forms $f(n) = N$ and $f(f) = F$, in which n is the value of $\frac{r_2}{r_1}$ and f is a function of the coefficient of fluid friction. Values of N have been given in Tables I–IV, for various values of h_c, the head due centrifugal action, and those of $f(f)$ are easily calculated when the elements and action of the wheel are given.

The expressions for head and efficiency then become, for the first form of wheel, friction included.

$$h_1 - h_2 = \frac{n^2+1}{2g}(2\,ar_1v_1 - a^2r_1^2) - Nv_1^2 \tag{62}$$

$$h_1 = \frac{1}{2g}(n^2v_1^2 \sec.^2\beta + 2ar_1v_1 - a^2r_1^2 - Nv_1^2 + Fv_1^2) \tag{63}$$

$$E = \frac{(n^2+1)(2arv_1 - a^2r_1^2) - Nv_1^2}{n^2v_1^2 \sec.^2\beta + 2arv_1 - a^2r_1^2 - Nv_1^2 + Fv_1^2}. \tag{64}$$

When $v_1 = ar_1$; $v_2 = nar_1 = nv_1$,

$$E = \frac{n^2+1-N}{n^2 \sec.^2\beta + 1 - N + F}; \tag{65}$$

when $n = 1$,

$$E = \frac{2-N}{\sec.^2\beta + 1 - N + F} \tag{66}$$

and when $\beta = o$,

$$E = \frac{n^2+1-N}{n^2+1-N+F}, \tag{67}$$

which becomes unity when F becomes o.

The magnitude of the quantity N which appears in the completed equations for efficiency and head may now be readily determined for the cases studied. It is not, as is easily shown, the value of $f(n)$,

which is obtained by considering only the absolute whirl, and as deduced in article 3.

Since the motion of the water in space is the resultant of the motion of the current relatively to the wheel and the motion of the wheel itself, it is evident that the path in space being given, the motion of the water at each point in that path may be decomposed into two components, the one coincident with the wheel, and the other the motion relative to the wheel and along the bucket channels. These two motions may be studied separately and their joint effect ascertained by combining the effects of their separate action.

The head driving the wheel being reduced by friction, the speed of wheel, $w_2 = v_2 = ar_2$, is correspondingly decreased. The value of v_2 is that due to the head.

$$H = (n^2 r_1^2 \sec.^2 {}_{\prime}\beta + 2arv_1 - a^2 r_1^2 - Nr_1^2 + Fr_1^2) \div 2g,$$

minus, the last term, *i. e.*, to

$$h_1 = H - h_f = (n^2 v_1^2 \sec.^2 {}_{\prime}\beta + 2ar_1 v_1 - a^2 r_1^2 - Nr_1^2) \div 2g,$$

and the speed of wheel must be adjusted to this last value of h. Friction produces a retardation of flow throughout the whole column of fluid.

25. It thus remains to determine the value of the factor, $Nr_1^2 = 2gh_c$, which enters all final equations. It is evident that it cannot be that value of $2gh_c$ found in the introduction as a measure of *total* centrifugal action, since only the motion of the water relative to the wheel is considered, when measuring the energy gained or lost relatively to the bucket. It must be some other value greater or less. The steadying effect, however, is approximately measured by the variation of the total centrifugal action for which values of $f(n)$ have been given, and these values are determined largely by the form of bucket. Variation of speed does not alter the path on the wheel, although it does vary velocity in that path.

As the difference of head on the entrance and exit sides of the wheel is due to the combined action of the two components of the absolute motion of the water, we obtain, for the difference of head due one, a maximum

$$h_c'' - h_c' = \frac{Na^2 r_1^2}{2g} = \frac{(n^2 - 1)\, a^2 r_1^2}{2g}, \tag{68}$$

and for that due the relative motion on the wheel, according to the theorem of Bernouilli,

$$h_r' - h_r'' = \frac{V^{2\prime\prime} - V^{2\prime}}{2g}. \tag{69}$$

The net difference of head is then,

$$h_p - h_2 = h_c'' - h_c' - h_r' + h_r'' = [V'^2 - V''^2 + (n^2 - 1) a^2 r_1^2] \div 2g. \qquad (70)$$

When the total difference of head is zero,

$$V''^2 = V'^2 + (n^2 - 1) a r_1^2; \; V'^2 = V''^2 - (n^2 - 1) a^2 r_1^2, \qquad (71)$$

and the head due the relative velocity of exit from the wheel must be equal to the sum of the heads due initial relative velocity of current and centrifugal action.

When the difference of head due change of relative motion is zero, and no acceleration occurs in the bucket from that cause,

$$V''^2 - V'^2 = o; \; h_p - h_2 = (n^2 - 1) \frac{a^2 r_1^2}{2g};$$

and the total difference of head is that due maximum centrifugal action.

But, in the analysis which has been given, only the relative motion on the wheel has been taken into account. That component which coincides with the motion of the wheel must, in turbines having wide crowns, be considered, and its effect in producing change of head in the wheel must be determined. This change of head is that due centrifugal force and, as this component of the motion of the water coincides with that of the wheel, the effect of centrifugal action, so far as it is due to this component, must be that obtained in Case I, and when $v_1 = a\, r_1$, we shall have for its measure

$$N = f(n) = n^2 - 1 \qquad (72)$$

the values of which expression are given in Table I.

Introducing this value of N into the equations for efficiency and head, for the case of the turbine of uniform direct flow, they become

$$E_{\text{max.}} = \frac{n^2 + 1 - N}{n^2 \sec^2. \beta + 1 - N} = \frac{2}{n^2 \tan.^2 \beta + 2} \qquad (73)$$

$$2gh = n^2 v_1^2 \sec.^2 \beta - N v_1^2 = (n^2 \tan.^2 \beta + 2) v_1^2 \qquad (74)$$

which, when $\beta = o$, give $E_{\text{max.}} = 1$ as before, and $h = \frac{v_1^2}{g}$ *i. e.*, h_1 is twice the height due the whirl v_1, which condition is essential to maximum possible efficiency.

When the form of the bucket-channel is changed the total centrifugal action is altered, but the difference of head due the relative velocity of the current is also changed and since, in all cases, the total difference of head at the entrance and exit sides is the sum of the head due the maximum possible amount of centrifugal action and that due

the change of relative motion within the wheel, it becomes evident that a difference of form such as distinguishes the Whitelaw wheel from the Barker mill, the velocity of exit remaining unchanged, simply alters the method of variation of pressure within the passages of the wheel without affecting its efficiency, or its best speed, however the total centrifugal action may be modified by such changes of absolute velocity of whirl within them. The values of $f(n)$ given above in Tables II–IV for total centrifugal action corresponding to various methods of actual variation of whirl are, therefore, not of importance in the theory of the turbine, so far as the treatment here adopted is concerned. They relate to the motion of the water in space, and when that path is rectilinear, and when the total head due centrifugal force is zero, the quantity $Nar^2 = (n^2 - 1)\ a^2r^2$ will, nevertheless, appear in the analysis. With wheels having narrow crowns, both this and the total centrifugal action may be neglected.

25. The Segner or Barker wheel illustrates the maximum effect of centrifugal force. In its rudest form the total centrifugal action is a maximum, the relative velocity of the water in the wheel does not change, and neglecting friction, when $v_2 = w_2 = ar_2$, $h_c = \frac{a\,r_2^2}{2g}$;

$$E = \frac{1 - N}{\sec.^2 {}_1\beta - N}$$

which becomes $E = 1$, when ${}_1\beta = o$.

But $v_2 = \infty$, since, for $E = 1$, we must have

$$v_2^2 = 2gh_1 + a^2r_2^2;\ v_2 = ar_2$$

and this is only possible when the quantity $2gh_1$ becomes indefinitely small in comparison with $a^2\,r_2^2$.

It then follows that the head, h_2, at exit is

$$h_2 = h_1 + \frac{a^2r_2^2}{2g} \qquad (75)$$

$$v_2 = \sqrt{2gh_2} = \sqrt{(2gh_1 + a^2r_2^2)}. \qquad (76)$$

The energy due this velocity is

$$U_1 = \frac{DQ}{2g}(2gh_1 + a^2r_2^2). \qquad (77)$$

The absolute velocity of exit, V_2, is, otherwise,

$$V_2 = v_2 - ar_2 = \sqrt{(2gh_1 + a^2r_2^2)} - ar_1\ ; \qquad (78)$$

and the energy wasted is

$$U_2 = \frac{V_2^2}{2g} = \frac{DQ}{2g}\left(\sqrt{2gh_1 + a^2 r_2^2} - ar_2\right)^2 \tag{79}$$

The energy utilized is then

$$U = U_1 - U_2 = \frac{DQ}{2g}\left[(2gh_1 + a^2r_2^2) - \left(\sqrt{2gh_1 + a^2r_2^2} - a\,r_2\right)^2\right]$$

$$= \frac{DQ}{2g}\left(2\,a\,r_2\sqrt{2gh_1 + a^2r_2^2} - a^2r_2^2\right) \tag{80}$$

which approximates to DQh_1 as ar_2 approaches infinity; for developing $\sqrt{2gh_1 + a^2r_2^2}$, by the binomial formula,

$$U = \frac{DQ}{g}.\ ar_2\left(\frac{gh_1}{ar_2} - \frac{g^2h_1^2}{2a^3r_2^3} + \text{etc.}\right);$$

which gives, when $ar_2 = \propto$,

$$U = DQh_1.$$

The efficiency is

$$E = \frac{U}{U_1} = \frac{2a\,r_2\sqrt{2gh_1 + a^2r_2^2} - a^2r_2^2}{2gh_1 + a^2r_2^2}; \tag{81}$$

and, taking $Z' = \frac{ar_2}{\sqrt{2gh_1}}$,

$$E = \frac{2z'\sqrt{1 + z'^2} - z'^2}{2 + z'^2}, \tag{82}$$

which increases toward unity, as a limit, as z' increases, without limit.

If centrifugal action could be neglected, taking the initial velocity and its proportion of the head V_1, and $\frac{V_1^2}{2g}$, as zero, the pressure head is $h_p = h_1$ and by Bernouilli's Theorem, since

$$h_1 = o + h_p \text{ and } o = 2g\,(h_1 - h_p),$$

the relative velocity of exit, V'', is such that

$$V''^2 = 2gh_1.$$

26. The distribution of energy in the turbine is easily determined in the special cases already studied. It may be traced, in a still more general and complete manner, by obtaining a measure of the velocity, absolute and relative, step by step, as the water passes through the turbine, without reference to the proportions of the wheel and without prescribing the method of flow.

Certain fixed relations always exist between the angles and the velocities of wheel and of water which may be easily determined.

Since the volume of flow is the same, wherever measured,

$$Q = 2\pi r_1 d_1 V_1 \text{ sin. } \alpha = 2\pi r_2 d_2 V'' \text{ sin. } \beta;$$

$$\frac{\text{sin.}\alpha}{\text{sin.}\beta} = \frac{n d_2 V''}{d_1 V_1} \tag{83}$$

When the velocities, V_1 and V'', are decomposed into radial flow, u_1 and u_2, and whirl, v_1, v'',

$$\text{tan. } \alpha = \frac{u_1}{v_1}; \text{ tan. } \beta = \frac{u_2}{v''} \tag{84}$$

$$\text{tan. } \alpha = \frac{u_1}{V_1 \text{ cos. } \alpha}; \text{ tan. } \delta = \frac{u_1}{V_1 \text{ cos. } \alpha - w_1} \tag{85}$$

which becomes tan. δ = tan. α when $w_1 = 0$, and $\delta = 90°$ when $w_1 = V_1$ cos. α. α becomes greater than a right angle when $w_1 > V_1$ cos. α.

Also,

$$V_1 \text{ sin. } \alpha = V^1 \text{ sin. } \delta; \ V_1 \text{ cos. } \alpha - V' \text{ cos. } \delta = w_1,$$

$$\frac{V'}{V_1} = \frac{\text{sin.}\alpha}{\text{sin.}\delta}; \quad V_1 = \frac{V^1 \text{ sin. } \delta}{\text{sin. } \alpha}; \ V' = \frac{V_1 \text{ sin. } \delta}{\text{sin. } \alpha};$$

$$\frac{V_1}{w_1} = \frac{\text{sin. } \delta}{\text{sin. } \delta \text{ cos. } \alpha - \text{sin. } \alpha \text{ cos. } \delta} = \frac{\text{sin. } \delta}{\text{sin.} (\delta - \alpha)} \tag{86}$$

and the ratio of the areas of sections is

$$\frac{O_2}{O_1} = \frac{V_1}{n w_1} = \frac{\text{sin. } \delta}{n \text{ sin. } (\delta - \alpha)} \tag{87}$$

To avoid disturbance at the entrances to the wheel-passages, the line of the tangent to the entrance side of the bucket must be coincident with that of the relative motion of the current entering the wheel; *i. e.*,

$$(V_1 \text{ cos. } \alpha - w_1) : V_1 \text{ sin. } \alpha = 1 : \text{tan. } \delta; \text{tan. } \delta = \frac{V_1 \text{ sin. } \alpha}{V_1 \text{cos.} \alpha - w_1} \tag{88}$$

In all cases, also,

$$\text{tan. } \alpha = n^2 \frac{w_1 d_2}{v_1 d_1} \text{ tan. } \beta \tag{89}$$

The velocity, V_1, of the water leaving the guides is due to the dif-

ference of pressure caused by the difference of head within and without these orifices. The total head, H, is reduced by friction to

$$h_1 = H - h_f;$$

The difference of head at entrance to, and exit from, the guides is $h_1 - h_p$ and the velocity of exit is

$$V_1 = \sqrt{[2g(h_1 - h_p)]} = \sqrt{[2g(H - h_f - h_p)} \quad (90)$$

$$\text{and its energy is } DQ = \frac{V_1}{2g} \quad (91)$$

Or, h_p being unknown and V_1 given,

$$h_p = h_1 - \frac{V_1^2}{2g} \quad (92)$$

The relative velocity of entrance into the wheel, V', is such that the relative energy is there

$$DQ\frac{V'^2}{2g} = \frac{DQ}{2g}(V_1^2 + w_1^2 - 2V_1 w_1 \cos. a) \quad (93)$$

The stream enters the bucket-channels with the velocity V' and with the above energy. This relative velocity and this energy are retained in the buckets, friction being here neglected, except as they are modified by centrifugal action, which increases the velocity in outward-flow wheels, and decreases it in inward-flow turbines.

The final relative velocity becomes V'' at the discharge side of the wheel, and the relative energy is there

$$\frac{DQ}{2g}V''^2 = \frac{DQ}{2g}\left(h_p - h_2 + \frac{V'^2}{2g} + 2gh_c\right)$$

$$= DQ\left[(h_1 - h_2) + \frac{w_1^2 - 2V_1 w_1 \cos. a + 2gh_c}{2g}\right] \quad (94)$$

But,

$$V_1 = \frac{V''O_2}{O_1}; \text{ and } w_2 = nw_1$$

$$\therefore V''^2 = 2g(h_1 - h_2) + w_1^2 - 2\frac{O_2}{O_1}w_1 V'' \cos. a + 2gh_c$$

$$V'' = \sqrt{\left[2g(h_1 - h_2) + \frac{O_2^2}{O_1^2}w_1^2 \cos.^2 a + 2gh_c\right]} - \frac{O_2}{O_1}w_1 \cos. a \quad (95)$$

It is impossible, in these turbines, to make $\beta = o$, as this angle must be large enough to permit free discharge of the volume of flow, Q, without high velocity, u_2, of direct flow; it must always be so large that

$$\tan.\ \beta = \frac{u_2}{w_2} \tag{96}$$

But this value is usually small enough to permit the common assumption that $V'' = w_2$; and as $\frac{w_2}{w_1} = \frac{r_2}{r_1} = n$; $\frac{w_1}{r_1} = \frac{w_2}{r_2}$;

$$V''^2 = 2g\,(h_1 - h_2) + n^{-2} V''^2 - 2\ V''^2 \cos.\ a\ \frac{O_2}{nO_1} + 2gh_c;$$

$$w_2 = V'' = \sqrt{\frac{2g\,(h_1 - h_2) + 2gh_c}{1 + 2\,\frac{O_2}{nO_1} \cos.\ a - n^{-2}}} \tag{97}$$

Negleeting centrifugal action, and making $a = 90$, we should have for turbines without guide-curves, were the case possible,

$$w_2 = V'' = \sqrt{2gh_1}$$

as before, when β, w_1, r_1, and h_2 become o and $n = a$.

When the head is so equally divided that we may make

$$h_1 - h_p = h_p + h_c \text{ and } V_1 = V''; \ w_1 = V_1;$$
$$h_1 = 2h_p + h_c;$$

we obtain

$$V''^2 = V_1^2 = 2g\,(h_1 - h_2) + w_1^2 - 2\,V_1 w_1 \cos.\ a + 2gh_c$$

$$= \frac{2g\,(h_1 - h_2) + 2gh_c}{2 \cos.\ a} \tag{98}$$

which, when $n = 1$, $h_2 = o$, and $h_c = o$, becomes

$$V_1^2 = \frac{2gh_1}{2 \cos.\ a} \tag{99}$$

The absolute velocity of exit, V_2, is the resultant of the motion of wheel and of the discharged current.

$$V_2^2 = V''^2 + w_2^2 - 2\,V'' w_2 \cos.\ \beta \tag{100}$$

and the energy thus lost is

$$U_2 = DQ\,\frac{V_2^2}{2g} \tag{101}$$

which approaches zero as the values

$$\beta = 0,\ V'' = w_2$$

are approached.

The value of w_2 may be obtained in terms of the angles a and δ; thus

$$w_2 = \sqrt{\frac{2g\,(h_1 - h_2) + 2gh_c}{1 + 2\,\dfrac{\text{cos. } a \text{ sin. } \delta}{n^2 \text{ sin. } (\delta - a)} - n^{-2}}} \qquad (102)$$

$$w_1 = \frac{w_2}{n} = \sqrt{\frac{2g\,(h_1 - h_2) - 2gh_c}{n^2 + 2\,\dfrac{\text{cos. } a \text{ sin } \delta}{\text{sin. } (\delta - a)} - 1}} \qquad (103)$$

For the value of the head, h_p, we have

$$h_p = h_1 - \frac{V_1^2}{2g} = h_1 - \frac{w_1^2}{2g} \cdot \frac{\text{sin.}^2\,\delta}{\text{sin.}^2\,(\delta - a)}; = h_1 -$$

$$\frac{(h_1 - h_2 - h_c)\,\text{sin.}^2\,\delta}{n^2 \text{ sin.}^2\,(\delta - a) + 2 \text{ cos. } a \text{ sin. } \delta - \text{sin. } (\delta - a) - \text{sin.}^2\,(\delta - a)} \qquad (104)$$

For the parallel-flow wheel, in which $n = 1$, $N = 0$, when $w_2 = V''$,

$$w_2 = \frac{g\,(h_1 - h_2)}{V_1 \text{ cos. } a}$$

an equation used by Vallet in designing.

The velocity V, due to the whole effective head, is

$$V = \sqrt{2g\,(h_1 - h_2)}$$

and, hence,

$$2w_2 V_1 \text{ cos. } a = V^2;\ w_2 = \frac{V^2}{2\,V_1 \text{ cos. } a} \qquad (105)$$

The useful head is

$$h_e = h_1 - \frac{V_2^2}{2g} \qquad (106)$$

and the efficiency is

$$E = \frac{h_e}{h_1} = \frac{h_1 - \dfrac{V_2^2}{2g}}{h_1} = 1 - \frac{V_2^2}{2gh_1}$$

$$= 1 - \frac{d_1}{d_2}\,\frac{\text{tan. } a}{\text{tan. } \beta}(1 - \text{cos. } \beta) \qquad (107)$$

The value of the work of centrifugal action, DQh_c, in all these equations is, as in the preceding cases, not the *total* work of absolute motion but the work due to that component which is coincident with the wheel and $h_c = (n^2 - 1)\, a^2 r_1^2$. But since, in the general case, the relations of whirl, of wheel, and of water are not fixed, the equation cannot be simplified as in the case of the turbine of uniform radial flow.

27. The form of curves for guides and buckets is evidently not prescribed by the general theory of the turbine. The angles, α, $_{\prime}\beta$ and δ, the proportions of the wheel, its principal dimensions, and the cross-sections of the passages, are determinable, and the values obtained are usually consistent with a wide variety of forms of curves. In many cases, also, the curve may be very considerably modified, to suit the ideas of the designer, by slightly altering the diameters and depths of the wheel. Thus, an increase of depth at the outer periphery reduces the velocity of direct flow and causes a corresponding change in the form of bucket, permitting a smaller value of the exit angle, $_{\prime}\beta$, than can be obtained with uniform direct flow, if the volume of water discharged be constant. Since the force exerted on the passing stream by the bucket or the guide is simply a deviating force, and since the angles of entrance and exit, only, are fixed by the theory of the wheel, it is obvious that the designer may, within certain limits, choose the form of the curve, to suit himself, or to meet any specified conditions.

The best form of curves is that which causes least loss of energy, and at the same time produces such total centrifugal action, if any, as may be best for the kind of wheel to be constructed, *i. e.*, that which gives minimum centrifugal action in outward and maximum in inward flow wheels. The losses of energy are due to friction and malguidance, and both these wastes are least on curves of smallest curvature. Centrifugal action is usually a maximum on curves of small curvature, and on those which deviate least at the terminal end, while it is zero when the path of the water in space is a straight line, since its magnitude is determined entirely by the path in space, and not simply by the path on the wheel.

The curve may be "laid down" very readily by plotting the desired path in space on a full-size drawing of the wheel, and from it determining the path on the wheel. Or it may be obtained by tabulating a series of differences of absolute and relative velocities of the water and of velocities of wheel, and laying down the curve, step by step, as

the resultant of the motions of water and wheel. Or the path may be plotted directly from the equation of the curve.

28. The equations of these curves, in space and on the wheel, are readily derived thus:

The elementary angle, $d\gamma$, traversed on the wheel is the difference between the angles, $d\varphi$ and $d\theta$, traversed by the wheel and by the water. Then

$$d\gamma = d\varphi - d\theta \tag{108}$$

The angle moved through by the wheel is always directly proportional to the time, since the rotation of the wheel is uniform, and

$$d\varphi = cdt \tag{109}$$

The motions of the water, both in whirl and in direct flow, are determined by the designer. In illustration, take two common cases:

(1.) Let the path of the water in space be rectilinear and the retardation uniform, as in some turbines having narrow crowns.

The equation of the path is then

$$\Delta s = (r - r_1) \text{ cosec. } a \tag{110}$$

and, since retardation is uniform,

$$\frac{d^2 s}{dt^2} = - f \tag{111}$$

Then

$$d\varphi = cdt; \; ds = V_1 dt - ftdt \tag{112}$$

$$r - r_1 = \text{sin. } a \left(V_1 \frac{\varphi}{c} - \tfrac{1}{2} f \frac{\varphi^2}{c^2} \right) \tag{113}$$

and, for any value of φ,

$$\varphi_m = c \sqrt{\left(\frac{(r_m - r_1)^2}{\text{sin.}^2 a} + \frac{V_1^2}{c^2 f^2} \right)} - \frac{V_1}{f} \tag{114}$$

The values of the constants are easily determined. V_1 is the velocity of exit from the guide-curves, and is obtained from the equation

$$V_1 = \frac{u_1}{\text{cosec. } a} \tag{115}$$

The value of c is known when the speed of the wheel is given and f is fixed by the value of V_1, thus:

$$s_1 = \frac{V_1^2}{2f}; \; s_2 = \frac{V_2^2}{2f} = \frac{u_2^2 \text{ cosec.}^2 \beta}{2f};$$

$$s - s_1 = (r_2 - r_1) \operatorname{cosec.} \beta = \frac{V_2^2 - V_1^2}{2f} = \frac{u_2^2 \operatorname{cosec.}^2 \beta - V_1^2}{2f};$$

$$f = \frac{u_2^2 \operatorname{cosec.}^2 \beta - V_1^2}{2(s_2 - s_1)} \qquad (116)$$

making $u_2 = bu_1$,

$$f = V_1^2 (b^2 \operatorname{cosec.}^2 \alpha - 1) \div 2(s_2 - s_1) = \frac{V_1 \sin. \alpha}{2(r - r_1)} (b^2 \operatorname{cosec.}^2 \alpha - 1) \qquad (117)$$

Common values are $V_1 = 0{\cdot}7 \sqrt{2gh_1}$; $u_1 = u_2 = 0{\cdot}2 \sqrt{2gh_1}$; $b = 1$; $\alpha = 20°$.

In the above case, no centrifugal action occurs.

(2.) Let the direct flow be uniform and the whirl uniformly retarded as in the turbines of Vallet.

We have, for the path in space, $rd\varsigma = vdt$; $dr = cdt$; $dv = d. \frac{r_2 - r}{r_2 - r_1} r_1$; $rd\theta = vdt$.

When the path has been extended from r_1 to mr_1, since $\frac{r_2}{r_1} = n$,

$$\theta_m = \frac{r_1}{c(n-1)r_1} \int_{r_1}^{mr_1} (nr_1 - r) \frac{dr}{r};$$

$$= \frac{r_1}{c(n-1)} (n \log_e m - m + 1) \qquad (118)$$

When $m = n$,

$$\theta n = \frac{r_1}{c(n-1)} (n \log_e n - n + 1) \qquad (119)$$

The values of θn locate the position of the terminal of the curve. For the path on the wheel and the form of bucket,

$$\varsigma = \frac{w_2}{r_2} = \frac{w_1}{r_1}; \; dr = cdt; \; rd\theta = vdt;$$

$$rd\varsigma = \frac{w_1}{r_1} rdt; \; d\gamma = d\varsigma - d\theta; \; v = \frac{r_2 - r}{r_2 - r_1} r_1;$$

$$d\gamma = \left(\frac{w_1}{r_1} - \frac{v}{r}\right) dt;$$

$$= \left(\frac{w_1}{cr_1} - \frac{nr_1 - r}{c(n-1)r_1 r} r_1\right) dr \qquad (120)$$

$$\gamma_m = \int_{r_1}^{mr}\left(\frac{w_1}{er_1} - \frac{nr_1 - r}{e(n-1)r_1}\right)\frac{dr}{r};$$

$$= \frac{w_1}{e}(m-1) - \frac{v_1}{e(n-1)}(n \log_e m + m - 1) \qquad (121)$$

and when $m = n$,

$$\gamma_n = \frac{w_1}{e}(n-1) - \frac{v_1}{e(n-1)}(n \log_e n + n - 1) \qquad (122)$$

which are the equations of the bucket curve and path of the water on the wheel. Making $w_1 = o$, we have $\gamma_m = -\theta_m$.

When $w_1 = v_1$, as in the turbine of uniform direct flow of which the theory has been given,

$$\gamma_m = \frac{v_1}{e}\left(m - 1 - \frac{n \log_e m}{n-1} - \frac{m-1}{n-1}\right) \qquad (123)$$

$$\gamma_n = \frac{v_1}{e}\left(n - \frac{n \log_e n}{n-1} - 2\right) \qquad (124)$$

Equations may be similarly derived for any practicable method of flow which the engineer may desire to secure. It will, however, be sometimes found impracticable to adopt certain forms of bucket with certain proportions of wheel, and only careful study will determine the best arrangement.

29. "Centrifugal" pumps, which are to be considered as reversed turbines, and in which centrifugal action may or may not greatly modify the relative motion of the water passing through their channels, are subject to the same laws, and the common theory of their action is to be modified in a similar manner. The remarks above made, in regard to forms of bucket and methods of determining their curves, also apply to this class of machines and the methods to be pursued in securing minimum wastes of energy are the same as for turbines. There is, however, one important difference to be noted between the turbine and the pump, viz., the heads due their action differ by the quantity $2h_f$, since friction opposes motion either toward or from the machine. For the turbine, $h_1 = H - h_f$; for the pump, $h_1 = H + h_f$, the head reaching and driving the turbine differing from that sustained by the pump by the quantity

$$H + h_f - (H - h_f) = 2h_f.$$

NOTE:—In the debate which followed the reading of the above paper, the author stated that he, when developing the expressions for

"total" centrifugal force presented at the opening of the paper, expected that they would find a place in the equations forming the theory of the wheel, but that as seen later in the paper, they are not so applicable. The equations remain as in the accepted theory, which is correct in form, although he believes that it will prove necessary to revise the nomenclature somewhat. The so-called "centrifugal" action is hardly that which is so understood popularly. He shows that the spiral of the Whitelaw Wheel does not permit the removal of the expression for so-called centrifugal force from its equation as its inventor thought (See J. F. I., for September); that Wheel and the Barker Mill have the same theory.

Hoboken, July, 1883.

Jules Duboscq.—Duboscq has been honored with two gold medals by the Société d'Encouragement. The first was granted in 1855, for his electric regulator, the second in 1857, for his improvements in the stereoscope, which contributed to the great and rapid popularity of that wonderful invention of Wheatstone and Brewster. He has since continued to devote his attention to the development of optics, and he is now considered everywhere as the master of experimental art in all branches of that interesting science. The introduction of the electric regulator into the projecting lantern was of immense value; his subsequent improvements in the oxyhydrogen lamp made the projecting lantern applicable to all varieties of experiment. At the exposition of 1855, Duboscq showed, for the first time, the projection of magnified photographs of microscopic objects, which gave images upon the screen similar to those of the solar microscope. By an ingenious combination he also obtained the effect of the polyorama, with a single luminous source, and projected upon the images of microscopic objects that of a micrometer which showed the true magnitude. His inventions for presenting the images in their natural positions, for projecting objects in a horizontal as well as in a vertical plane, for exhibiting all the phenomena of polarization, for showing spectra in relief and the various forms of turning spectra, are but a few of the results for which the scientific world is indebted to his ingenuity. His assistance has also been very useful to many other experimenters in their researches. Especial mention may be made of the practical success which he gave to Jellett's saccharimeter, and to Bertin's acknowledgement of his valuable assistance in the study of magic mirrors.—*Bul. de la Soc. d'Encour.*, Feb. 1883. C.

WATER-LINE DEFENCE AND GUN-SHIELDS FOR CRUISERS.

By N. B. CLARK, Passed Assistant Engineer, U. S. N.

[From the Proceedings of the U. S. Naval Institute; revised and considerably enlarged by the author for publication in the JOURNAL.*]

"An examination of facts is the foundation of science."

A well designed war-ship may be termed an aggregation of compromises. The augmentation or extension of any quality beyond a certain limit can only be made at the expense and by the curtailment of some other requisite, equally, or perhaps more, desirable.

Everything has weight, and to carry weight requires displacement, which involves increased resistance and greater engine power. The distribution of weights so as to produce the best general results is a problem of the greatest importance, for upon it depends the success or failure of the vessel, as measured by the standard of comparison with others.

The cardinal requisites of a war-ship, mentioned in the order of their importance, are:

1st. Defensive power—ability to keep the ship afloat, and the crew alive.

2d. Offensive power—ability to destroy or disable an enemy's ships and men.

3d. Mobility—power to chase down or ram an enemy.

4th. Quarters—giving healthful and sanitary accommodations to officers and men, necessarily conducive to proper morale and discipline.

Of these prime requisites, defence of the water-line is, to a war-ship, a matter of paramount importance; for even though a vessel had the speed of the wind, was armed with the most powerful guns, commanded by the most capable officers, and manned by the bravest crew, all would avail nothing if she could not be kept afloat in combat.

The great improvements attained in the rapidity of manipulation,

* No. 25, Proceedings U. S. Naval Institute, "The Development of Armor for Naval Use," by Lieutenant E. W. Very, U. S. N., a member of the Naval Advisory Board, having been published after this paper, in its original form, was read before the Washington Branch (June 7, 1883), has necessitated some revision and additions by the author, to correct certain statements by Lieutenant Very in relation to the curved shield, which are herein claimed to be erroneous.

accuracy of fire and range of the modern breech-loading rifle guns, make the defence of the water-line a matter for the most serious consideration. Percussion shells of large size, each one of which is in itself a mine, will render an efficient defence of the water-line a problem very difficult of solution. But even if absolute protection cannot be attained, the importance of the matter demands the adoption of every available expedient that may lessen the chances of fatal disaster and ensure the flotation of the ship—1st, by keeping the water out, as far as possible; 2d, by freeing the vessel of water, should it unfortunately gain entrance.

A water-line defence, consisting of armor disposed vertically, is at the mercy of *elongated* shot, concentrating their energy on the small area of their cross sections; and if such armor extends the length of the vessel, the narrow bow and stern are encumbered with a weight entirely disproportioned to their flotative power.

Vertical side armor does not give an efficient protection, unless supplemented by deck-plating; but if the aggregate weight of the vertical armor and deck-plating is distributed over the vessel in the form of a curved shield, having a cross section conforming to the arc of a circle, extending across from side to side, and so placed within the ship as to have its crown slightly above the water-line, with the sides attached to the vessel some four feet below it at ordinary load draught, a much greater measure of protection can thereby be obtained with the same weight of armor; as elongated shot strike it upon their sides, thereby presenting the much greater area of their longitudinal sections, by which they would be deprived of much of their penetrating power. Moreover, the glancing effect of a curved shield will enable a comparatively light plate to throw off a heavy shot.

Immense energy is stored in a projectile by propelling it by as great a pressure of an elastic gas as the gun will safely bear without rupture, from the breech to the muzzle thereof; this energy is accumulated from transverse strains on successive sections of the length of the bore, transformed into longitudinal motion. As the energy is acquired during the time of the passage of the shot from the breech to the muzzle of the gun the time element is an important factor.

When a shot strikes armor at right angles to its surface, this enormous energy, gradually acquired, is sought to be resisted during the infinitesimal time the shot at its immense velocity is passing the almost inappreciable distance the armor will stretch before breaking; con-

sequently projectiles can be made to penetrate a thickness of armor much greater than the sides of the gun from which they were fired. By disposing plates at an acute angle to the line of fire, a much greater time element is given to the armor which will enable it to resist the energy of the projectile.

In order to obtain the best result with deflecting armor it must have a hard surface, and the plate should have sufficient rigidity to turn the end of the projectile. If the plate is soft, so as to permit the shot to bite, or if it does not possess sufficient rigidity to turn the end of the projectile before it obtains a facing, it may go through.

When a projectile strikes a deflecting surface sufficiently hard and rigid to deflect it, the angle of deflection is about equal to the angle of incidence and its action is, therefore, analogous to the reflection of light, when impinging on a bright surface. When the projectile force is far in excess of the resistance of an inclined plate, the shot in going through turns in a direction normal to the surface of the plate, its action being analogous to the refraction of light—when passing through a transparent medium—and for the same reason, as it moves in the direction of the least resistance, there being a less thickness of plating in a direction normal to the surface, than in an oblique direction.

When a projectile of high velocity impinges upon an acute deflecting surface, it receives so severe a drubbing from the area of the plating acted on, being largely in excess of its own surface, that the shot is usually broken up, even by very light plating.

The principle of deflection as a means of defence is by no means new, as it was applied in the shields of the soldiers of ancient Rome, and is applied in those of many uncivilized tribes of the present day.

The application of the principle of deflection for the protection of war-ships dates back to the beginning of the present century, a United States patent having been granted for such a design as early as 1804.

The Confederate government, during the late war, constructed all their armored vessels upon the deflective principle; and the vessels then built proved remarkably successful, when the great difficulties under which they were constructed are taken into consideration; but the angles of incidence presented were entirely too great to obtain the best results.

If the angles of incidence are reduced, the protected space within is correspondingly contracted, so that it is doubtful if much advantage can be gained by the general application of inclined plates; but by

restricting the application of deflecting armor to certain structural combinations, great advantage, both in the reduction of weight and increased protection can be obtained by its use.

The Confederate armored vessels *Atlanta* and *Tennessee* had the plates of their casemates inclined at an angle of about 30°, such a disposition constricted the interior space and thereby interfered with the proper working of the guns, while it is doubtful if there was much gain from the deflective action, and consequently of weight at so large an angle. The same interior space, defended by an equal weight of vertical armor, would probably give almost as great a measure of protection; but this disposition had this advantage for the Confederates, it enabled them to obtain a greater measure of protection with the light plating, which their meagre facilities permitted them to produce, than could have been obtained by a vertical disposition of the same thickness of plating. In the plans herewith presented it is intended to keep the angle of incidence down to a maximum of 15°.

Curved deflecting armor will give great advantages over that having plane inclined sides, owing to the angle of clearance which the curve affords. The Confederates used curved deflecting armor in the construction of the Hollins' ram which, above the water, was of a turtle back form. The difficulty here encountered was that by enveloping the entire exterior of the vessel in armor, in order to obtain a sufficient margin of buoyancy, the horizontal angle of incidence was made so great that but little advantage was obtained from the deflective principle; while on the other hand if the horizontal angle of incidence was made sufficiently acute, by deeply submerging the vessel, the margin of buoyancy would be so much reduced as to render her liable to sink by the admission of a very small amount of water. These difficulties are overcome in the design of vessel herein described, by the combination of a curved shield with the hull of an ordinary vessel, producing an interior turtle back; the space above the curved shield being divided into water-tight compartments to be packed with water excluding stores, thereby giving a large margin of buoyancy, or life belt to the vessel.

By the aid of this combination of shield, hull and life belt, very acute angles of incidence at the water line are obtained for horizontal fire, whereby a large measure of protection is obtained with very light plating.

In the form of deflective vessel, in which the entire superstructure

is enveloped in armor, the height above the water is not sufficient to admit of the working of guns, such a design being only applicable to rams or torpedo boats. But in the form of vessel herein described the guns are mounted in separate shields far above the water line, the armor serving as a carriage for the gun, which being breech loading needs but a small protected space for its crew at the breech end; by this means the guns' crews are completely protected with the least possible weight of armor.

The zone of danger is the side of the vessel, alternately acted on by wind or water as the ship rolls. It is proposed to protect this vital part by interior deflecting armor. The position of the shield in relation to the water-line to be adjusted by the admission of water to the double bottom.

In combats between ships at ordinary fighting range, horizontal fire is all that need be considered—a vertical target can easily be struck, while it is almost impossible to make a projectile fired from a vessel rolling at sea strike a horizontal surface. Under such circumstances it would be very difficult to land a shot upon the area of an hundred-acre farm, to say nothing of the much smaller surface of a ship's deck. Curved fire from land batteries placed for the defence of channels is most effective, but such fire is impracticable in contests between vessels at sea, as an entire shipload of ammunition might be expended before making one successful shot.

When elongated shot fired from rifled guns strike the water, they tumble end over end and sink beneath the surface, and there is probably no instance known of such a shot striking a vessel below the water-line, unless her side was exposed by rolling. When the combatants are a certain distance apart, the intervening water serves as an impenetrable rampart for that portion of the ship below its surface. For every depression below the mean level of the water there is a corresponding elevation or protuberance above it; and these elevations or protuberances above the mean surface will most effectually deflect shot of high energy, and protect the side of the vessel below them; therefore, a vessel would not be exposed by the hollows between two waves, and if she was, a plane-sided shield would have no advantage over a curved one.

Figure 1 represents a cross section of a cruising vessel rolling in a sea way, being struck by a projectile which is deflected upwardly through the light penetrable upper works. This shield conforming to

the arc of a circle, described from a centre approximating the ship's centre of oscillation, presents a practically constant angle of incidence to horizontal fire as the ship rolls. It is not claimed that the curve of a circle will give the most constant angle of incidence to horizontal fire, as such would not be the case, for the true curve would partake somewhat of the nature of that of a parabola, and would, however, vary slightly with each change of the load or draught of the vessel; but the curve of a circle is an approximation near enough for practical purposes, and has the advantage of giving more protected space under the shield for boilers and machinery, and less room above it for water to enter, to endanger the buoyancy and stability of the ship; where it diverges from the true curve it is in the most advantageous direction.

Figure 2 represents a cross section of a turreted vessel having vertical side armor and horizontal deck plating, being struck by a projectile under similar circumstances to Fig. 1; the projectile penetrating the vertical armor and impinging against the under surface of the armored deck, is deflected downward through the bottom of the vessel, passing through one of the boilers on its way.

Figure 3 represents the plan view of the vertical 1" turret *A*, (Fig. 1) and Fig. 4 represents the plan view of the cylindrical turret *B* (Fig. 2), with the action of projectiles upon the same, respectively.

The portion of a deflecting shield, of any form, liable to be struck at any given instant consists of a zone of small area situated above, at, and very slightly below the mean water-level. This small imaginary zone is shifting in character, and on a curved shield of five feet rise, extending four feet below and one foot above the water-line, it would probably be about 18″ in height. The curved shield covers the entire zone of danger, five feet in height; and this smaller zone, consisting of the part liable to be struck by horizontal fire at any given instant, traverses the larger zone, more or less, according to the oscillations of the vessel, and protects it in detail by constantly presenting a great horizontal thickness of armor, with a very acute angle of incidence, and a very large angle of clearance to the part where the vast majority of shot strike.

Figure 5 represents a cross section of a cruiser, and three different forms of deflecting shields, numbered respectively 1, 2 and 3. They each have the same immersion, being secured to the sides of the vessel four feet below the water-line, and Nos. 1 and 2 rise one foot above it; but the angle of the plane-sided shield No. 3 being equal to the

angle of incidence of the curved shield No. 2 at the water-line, does not carry it to the same height.

No. 1 is the plane-sided shield proposed by the Naval Advisory Board for the cruiser Chicago, being the *fac-simile* of the official drawing. This shield presents so large an angle to horizontal shot at the water-line that it will afford no adequate protection with the light plating of $1\frac{1}{2}$ inches proposed. Besides presenting too large an angle to give protection, it also weighs considerably more than Nos. 2 and 3.

No. 2 is the curved deflecting shield—the form of water-line defence recommended by Act of Congress of August 5th, 1882, authorizing construction of new cruisers—conforming in cross section to the arc of a circle, and presenting a practically constant angle of impingement to horizontal fire at the water-line as the ship rolls, and that so acute as to make penetration very difficult with comparatively light plating.

A horizontal shot at the water-line would strike the curved shield at G; as the line IT is tangent to the arc at the point of initial impingement, it therefore represents the angle of the same.

The fact being that more shot would strike the curved shield above the water-line than below it, it is therefore making a concession to take G as the average angle, as, practically, the mean angle would be much less; and it should also be remembered that G is the initial angle of impingement, which, owing to the curved surface, rapidly diminishes as the shot glances along the plate. Such a curved shield would therefore possess a much greater deflecting efficiency than a plane-sided one, presenting the same angle of impingement, like Nos. 1 and 3, the angles of which would not decrease as the shot glanced along their surfaces, but would be liable to buckle up in front of the shot and be pierced by it; a contingency that would not arise with the curved shield, presenting the same angle, as the shot, owing to the curve, can much more easily free itself from the surface of the armor.

Shield No. 3 is drawn for the purpose of proving that it is impossible to construct a shield, having plane inclined sides, that will present so acute an angle to horizontal fire as the curved shield No. 2; or that will give as much room under it for boilers and machinery; or that will exclude the same amount of water from the part of the vessel above it; or that will give the same strength and stiffness to a vessel.

The line AE' is drawn parallel to the tangent IT, and the horizontal water-line cuts it at H. As the line AE' is drawn parallel to the tangent IT, therefore the angles G and H are equal. And as this

angle will not carry the crown of the plane-sided shield to the same height as the crown of the curved shield, the plane-sided shield will require a greater angle to attain the same height.

It will be apparent that the curved shield No. 2 contains under it the space represented by the segment contained between the arc AGE and its chord AE', in addition to that contained under the plane-sided shield No. 3.

Also as the segment is above No. 3 and below No. 2, the former will admit a volume of water into the ship above it, equal in cross section to the area of the segment $AGEAE'$, to endanger the buoyancy and stability of the vessel, which the round-up of the curved shield No. 2 would exclude.

The curved shield No. 2 is superior in these particulars to the plane-sided shield No. 1, or any other plane-sided shield, presenting the same angle, that can be constructed:

1st. It presents a more acute, and, practically, constant angle of impingement to horizontal fire, and one that with a moderate thickness of plating, if supplemented with coal or stores in water-tight compartments to augment the deflecting efficiency and exclude water, would afford a very substantial resistance to the fire of heavy guns, while the plane-sided shield would afford but a very small measure of protection.

2d. The plane-sided shield No. 1 would weigh considerably more than the curved shield No. 2, and would encumber a ship with the weight of armor without giving her the benefit of its protection.

3d. The curved shield, if anything like the same angle of impingement is presented, will contain much more room under it, for boilers and machinery, than an inclined plane shield, and is therefore admirably adopted for light draught vessels intended for service in the shoal waters of our Atlantic and Gulf coasts.

4th. With an equal angle of impingement, the round-up of the curved shield would exclude a large volume of water, which the plane-sided shield would permit to enter, and endanger the buoyancy and stability of the vessel.

5th. The curved shield will possess a much greater deflecting efficiency with any given angle, owing to the fact that the angle of clearance is a constantly increasing one, so that projectiles which would readily pierce a plane-sided shield can free themselves from the surface of the curved shield.

6th. The curved shield, tied in by the chords of its arc and supported on longitudinal and transverse bulkheads, in combination with the ships cellular bottom and sides, will give a vessel an efficiency and strength as a ram that is unprecedented. A vessel so built would form a scientifically constructed floating girder, having such rigidity as would permit of her being engined with the highest power. The curved shield with coal or stores above it, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt for the vessel, would make a ship almost unsinkable, while the plane-sided one would be such an element of weakness that a vessel fitted with it could only, with difficulty, be kept afloat in action.

In regard to the deflecting efficiency of light plates, disposed at an acute angle, the British Admiralty have made experiments at Portsmouth within the last two years for the purpose of testing deck armor, proving that a two-inch iron plate, entirely unbacked, simply supported on beams, disposed at an angle of 10°, would resist the penetrating power of the 18-ton, 10-inch gun; and that iron plates of three inches thickness, similarly placed, and disposed at an angle of 15°, would throw off shot from the same gun discharged from a distance of 100 yards.

If such good practical results can be obtained from iron plates, it is reasonable to expect that a much greater efficiency can be derived from homogeneous steel plates, combining hardness with toughness.

To determine the relative deflecting power of the curved and plane-sided shields in the absence of any very extensive experiments on inclined plates, we can only reason from results obtained with vertical armor, and, hence, to form a fair comparison it is reasonable to suppose that in all cases the velocity of the shot, resolved in a direction normal to the plates, is entirely destroyed, and that the striking force in each case will be that due to a shot of the same weight moving normal to the plate with a velocity equal to the normal velocity of the shot moving obliquely to the plate.

The penetrating power of the shot being measured by its intrinsic energy, or by $\frac{w \cdot v^2}{2g}$, then, on inclined plates the striking force would be $\frac{w \cdot v^2 \sin^2\theta}{2g}$, where θ is the angle between the direction of the shot and the tangent to the plate at the point of contact.

In the diagram, Figure 6, draw the tangent to the curve at the

water line, and lay off on the horizontal line a distance AO to represent v^2, draw AC parallel and OC normal to the tangent OT; lay off OB equal to OC, drop the perpendicular BD, then OD will equal $v^2 \sin^2\theta$, θ being the angle of inclination of the tangent to the horizon. Proceeding in the same way with the plane-sided shield, denoting the corresponding lines by corresponding letters, $O'D'$ will equal $v^2 \sin^2\theta'$, where θ' is the angle of inclination of the plane-sided shield to the horizon. The striking force exerted against the shields respectively will be represented by these lines multiplied by the same constant, and the relative protection afforded will be inversely as the lines, or as 5.4 to 1 in favor of the curved shield. But when it is taken into consideration that the curved shield allows the projectile to clear itself after striking, by a considerably increasing angle of clearance, between the curve OF and the tangent OT, it is evident that this ratio of protection will be consideraly increased in favor of the curved shield.

The other method of comparing the relative efficiency of the two shields is to measure the metal that would have to be displaced to effect penetration. In the case of the curved shield the distance through WR is $9\frac{3}{16}''$, there being $1\frac{9}{16}''$ greater distance through the metal of the curved shield than through a plane-sided shield presenting the same angle. The distance HI through the metal of the plane-sided shield No. 1 is only $3\frac{1}{4}''$.

In the case of vertical armor, experience has demonstrated that the energy required to penetrate plates of different thickness is proportional to the square of the thickness of the plate; and reasoning from this, we are led to conclude that in the case of inclined plates it will vary as the square of the distance measured through on a line making the same angle with the plate that the plate makes with the horizon.

Taking the shield before mentioned, the distance through, as measured on the water-line, in the case of shield No. 1, is $3\frac{1}{4}$ inches, and in the case of shield No. 3 the distance measures $7\frac{1}{2}$ inches, and the efficiency of the two shields would be directly as the squares of these quantities, or as 1 to 5·4. But as the curved shield affords a greater distance through, and allows the shot in glancing to clear itself more readily than a plane shield, it will be much more efficient than the above proportions show.

Notwithstanding the fact that the great superiority of the curved shield over the plane can be proved by unanswerable mathematical demonstrations, Lieutenant Very, a member of the Naval Advisory

Board, in his able and interesting article, "The Development of Armor for Naval Use" (No. 25, Proceedings U. S. Naval Institute), takes peremptory ground in favor of the plane over the curved shield; but I propose to show that both his premises and conclusions are erroneous.

On page 527 will be found this statement in reference to the comparative merits of the two shields: "In the United States it has been made a matter of much discussion whether this alteration from a curved to an angular disposition is an improvement, or a step backward. It seems, however, to be easily susceptible of proof that the angular arrangement presents most decided advantages." Upon the same page is the diagram Fig. 8, representing a curved and a plane shield on the same cross section, with the outline of a boiler *K* in position under them, for comparison. The top of the plane shield is represented as entirely below the water line, while the crown of the curved one rises far above it; but fairness of comparison in boiler capacity, under the two shields, required that both should have been given the same vertical height.

A casual, or an unscientific reader, from "a great respect for official utterances," might give this unqualified claim of "most decided advantages" of the plane over the curved shield, its face value, but a critical examination of the diagram with its explanatory context will show the claim to be unfounded. It is generally true that any theory is "easily susceptible of proof" where its advocate is allowed to make his own premises, but Lieutenant Very has failed even to draw correct conclusions from his voluntary assumptions.

The only special advantage claimed by Lieutenant Very—with the aid of his incorrect diagram, which can be conceded—is a very slight decrease of angle of the plane over the curve at the point *D* four feet below the water line, where projectiles virtually never strike. But when it is considered that this slight disadvantage for the curved shield at the point mentioned, is accompanied by a corresponding decrease of the angle of curve over the plane at the top of the shield, where essentially all projectiles do strike, this very slight advantage is conceded, admitting for this argument Lieutenant Very's delusive diagram. I am not advocating protection to that part of a ship where it is practically invulnerable to shot.

There have been winds so fierce as to destroy the strongest structures on shore, and there have been storms so violent as to founder the

staunchest ships at sea, and lightning so powerful as to make sport and fragments of either. Against such unusual incidents, intense as is the love of life, it has not been within the power of human thought adequately to provide. If men should seek to do it they would never build ships nor houses, but live in caves, and then not be absolutely safe from these immeasurable and irresistible forces. Such dangers are the inevitable risks of our living at all, and we build ships and go to sea in them, and build houses and live in them, and takes these risks, and we would be mere savages if we did not. In this category of extremely improbable chances would come the likelihood of a ship being struck by a projectile four feet below the water line during an engagement. Such a thing *may* happen, but experience shows that it is no more likely to occur than than the disasters of nature mentioned above.

Lieutenant Very quotes the geometrical axiom, "a straight line is the shortest distance between two points," a truth which no one will dispute, but what application it has to the question at issue is not so clear; as the outline of the plane shield is not represented by a single straight line, but of three straight lines with considerable angles at their points of intersection, and any one can see by referring to Fig. 5, that the arc of a circle representing the outline of a curved shield would be of less length than the three lines representing the plane-sided shield, and that a curved shield would weigh less than a plane-sided one of equal height.

If the curved and plane shields, represented in the diagram on page 527, were correctly shown as of equal height, the advantage in weight would be in favor of the curved; but the advocates of the plane are welcome to the infinitesmal advantage in this respect apparently obtained by the diagram.

This drawing also contains the outline of a boiler *K* in position under the shields, and the statement has been made by members of the Naval Advisory Board that the curved shield will not cover as great a height of boiler as the plane-sided one. This assertion is also incorrect, as an inspection of the diagram will show. If the boilers are set close out against the side of the vessel, no advantage whatever in height of protected space would be obtained by the curved shield, as the top of the boilers would have to be placed more than four feet below the water line, the same as when placed below a flat, under-water, armored deck, similar to that of the *Comus* class.

The top of the shield being placed below the water-line, if the sides of the vessel should be penetrated, then when the water-excluding stores are exhausted from the compartments above it, the *Comus* flat-deck would permit water to flow in and sink the vessel. The top of the shield should rise somewhat above the water-line in order to give the vessel a margin of buoyancy independent of the water-excluding stores.

If the boilers are placed part way out, in the position shown on the diagram Fig. 8, only a small measure of protection is obtained by the shield, owing to the large angle of incidence presented; and if they were placed all the way out at the same height, the shield would degenerate into vertical armor.

But any one can see, by referring to Fig. 8, that if the boilers are placed in their proper position, in the centre of the vessel, the curved shield there represented will cover a much higher boiler than the plane-sided one.

Lieutenant Very should not object to his own diagram proving more than he intended, for it only shows that in its construction he built wiser than he knew.

Such a disposition of the boilers will give the following advantages over that shown in the diagram, viz., it will admit of a central longitudinal bulkhead, dividing the under-water body into water-tight compartments, a device with which all large vessels should be provided; it affords greater safety to the boilers from the attack of torpedoes and rams in time of war, and danger from collision; it enables the firemen to obtain coal from side bunkers, or chutes from compartments above, directly in front of their furnace doors.

The greater height of protected space in the centre of the vessel afforded by the curved shield could be made available either by arranging the boilers with side fire-rooms, for which there is ample room, or by disposing them with athwartship fire-rooms.

A large proportion of the coal and stores should be carried in the compartments above the shield, to augment the deflective efficiency and exclude water, the effect on the stability of the ship being compensated for, when occasion requires it, by the admission of water to the double bottom. This would allow nearly all the space under the shield to be utilized for boilers, machinery and magazines, with passages from the same to the different guns. The stout tubes for training the vertical V shields by power applied beneath the curved shield,

also serve as conduits for conveying ammunition directly to the breech of the guns. By this means all exposure of men by the transportation of ammunition along the open deck is avoided.

Lieutenant Very makes the following statement on page 529; "It has been shown heretofore that a thickness of armor for the shield of less than four inches can scarcely be depended on at a greater angle than 20°. The average angle necessary for this shield is from 22° to 28°." These statements are strictly true, yet he, with a knowledge of these facts, as a member of the Naval Advisory Board proposed to apply $1\frac{1}{2}''$ thickness of plating to all the new ships in the form of plane shields disposed at angles of 27° and 28°, having a horizontal thickness of only $3\frac{1}{4}''$, while a curved shield of considerably less weight, covering boilers of equal height, would present and angle of only 13°, and a horizontal thichness at the water-line of $9\frac{3}{16}''$, which would afford eight times the resistance of the plane.

An examination of the next statement on page 529 proves it to be widely incorrect; "Where a two inch deck curved with a single radius is put in, the same weight would allow with the chord disposition, 4 inch plates on the side chords and $1\frac{1}{2}$ inch on the dead flat." Taking the cruiser *Chicago*, the ship of greatest beam, and therefore the one most favorable for the above hypothesis, we find the area of the flat top is not more than one-eighth greater than the area of the side planes. It would therefore be impossible to increase the thickness of the side planes more than $\frac{5}{8}$ of an inch by taking a half inch from the flat top, although two inches are claimed by Lieutenant Very. In the ships of less beam, *Boston* and *Atlanta*, a half inch taken from the flat top would not increase the thickness of the side planes as much as $\frac{1}{2}$ of an inch.

If the thickness of the sides of the plane shield can be augmented at the expense of the top, so likewise can the sides of the curved shield be increased in thickness at the expense of the top, by the application of taper plates; it is therefore not worth while to take this feature into consideration when comparing the merits of the two shields.

Lieutenant Very says on page 527: "The shield has now become universally recognized as a necessary attachment to all vessels, both armored and unarmored;" meaning of course the plane-sided form, to which he appears to be peculiarly attached, and on page 524 he lays great stress upon the importance of having the shield *well supported against flexure*, a point well taken, and I will ask which will

give, and which will require the most rigid support, the curved or the plane-sided shield? Undoubtedly the arched curve will afford the most unyielding support, while the plane-sided shield not giving so much, would require far more to enable it to deflect projectiles, as it does not possess the angle of clearance obtained by the curve.

In a plane shield of such light plating as $1\frac{1}{2}''$, disposed at so large an angle as 27°, the resistance would be so small in comparison to the power of the guns likely to be brought against it, that the full effect of the horizontal-distance through the plating would not be obtained; as the tendency, in such cases of disproportioned resistance to projectile force, is for the shot to turn in a direction normal to the surface of the plate; the reason of this is, as the projectile passes through the plate, there is a less thickness of metal under it than there is above it, and it follows the line of the least resistance; even light, at its immense velocity, follows the same general law; therefore, such a weak shield, aside from its affording no adequate protection, would be a positive source of danger in itself, from the downward deflection of projectiles, while a curved shield of equal thickness and less weight, presenting a much more acute angle of incidence, with a constantly increasing angle of clearance, would invariably deflect shot upwards.

Figure 5 is a fair and correct diagram for comparing the merits of the curved with the plane-sided shield, as both are of the same height, each being secured to the sides of the vessel four feet below the water line, and rising one foot above it.

With such a curved shield as No. 2, Fig. 5, of two inches thickness of plating, the horizontal distance through the plating on the water line would be 12·25″, and the angle presented at the same point would be 13°, while the horizontal distance through a plane-sided shield similar to No. 1, Fig. 5, of the same thickness of plating, would be 4·33″, and the angle presented would be 27°. This angle would of course be the same at all depths, and would be the average of the angles, in all positions, which would sometimes be greater and sometimes less, as the vessel rolled.

The horizontal angle of incidence of the curve would be practically constant in all positions, and the horizontal thicknesses of plating, and ratios of superiority of the curve over the plane at different points of immersion, would be as follows, viz:

Fig.1.

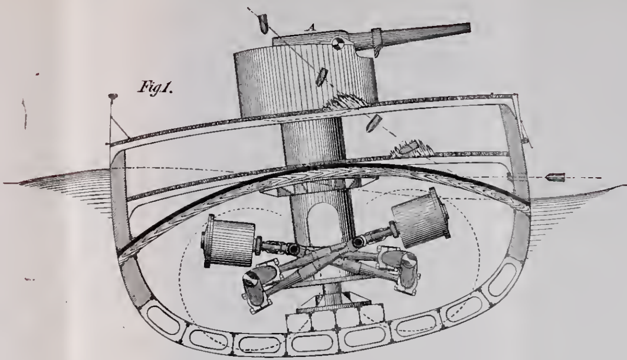


Fig.2.

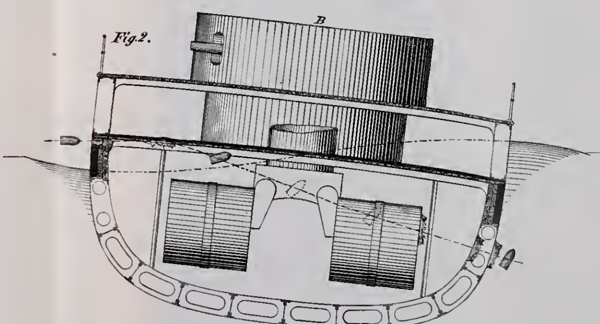


Fig.3.

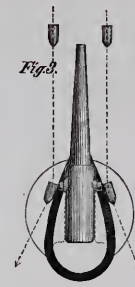


Fig.4.

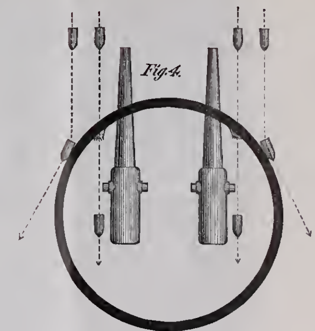


Fig.6.

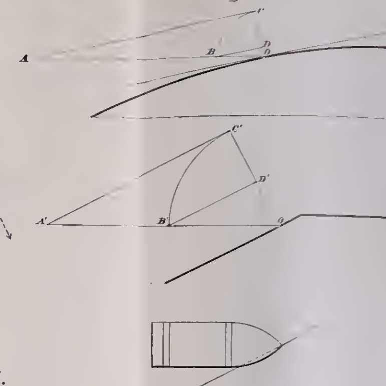
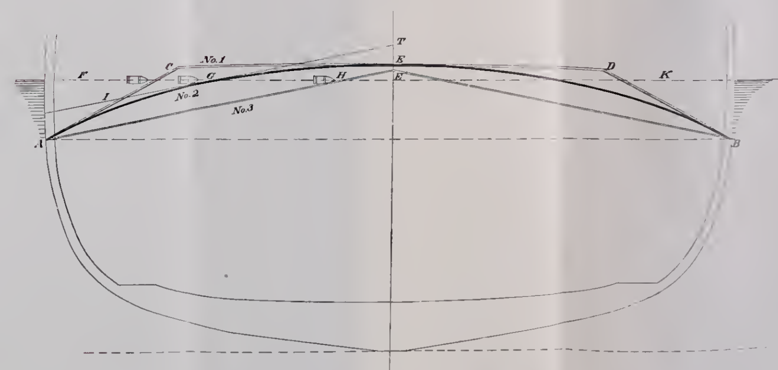


Fig.5.



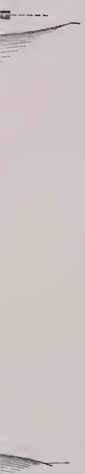


Fig.3.

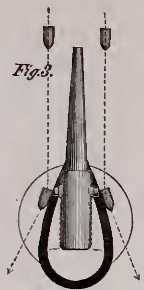


Fig.4.

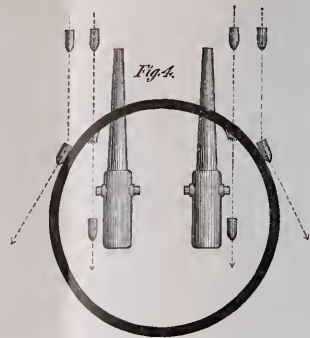


Fig.6.

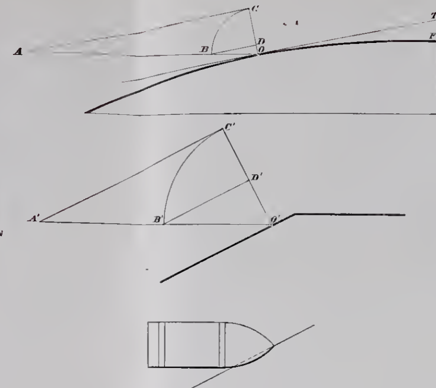


Fig.7.

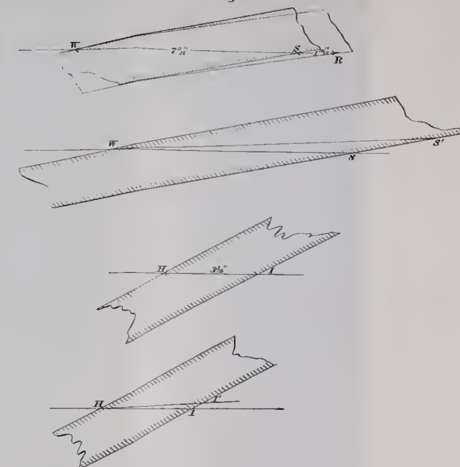


Fig.5.

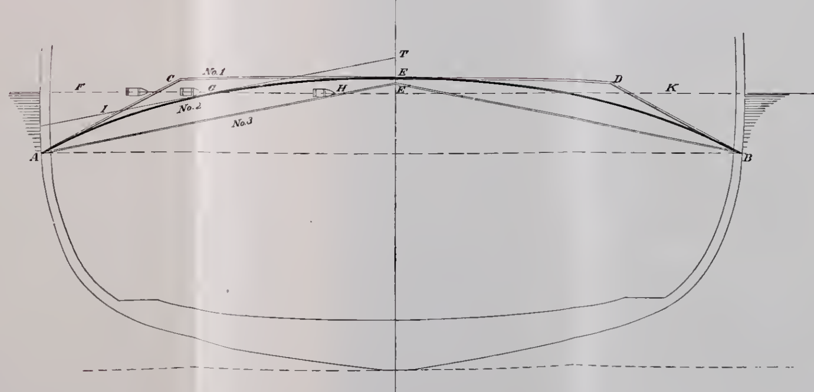
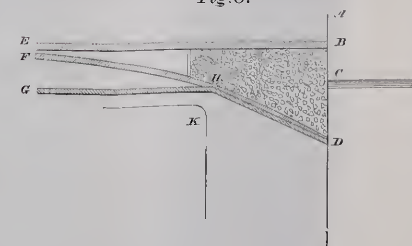


Fig.8.



	Horizontal thickness.	Superiority of curve over plane.
6″ above water line	18·5″	17·72 to 1
water line	12·25″	8 to 1
6″ below water-line	9″	4·32 to 1
12″ below water-line	7·75″	3·20 to 1
18″ below water-line	7″	2·61 to 1
24″ below water-line	6·25″	2·08 to 1
30″ below water-line	5·5″	1·61 to 1
36″ below water-line	5·25″	1·47 to 1
42″ below water-line	5″	1·32 to 1
48″ below water-line	4·75″	1·20 to 1

From the above list of horizontal thicknesses of plating, and ratios of resistance at different depths of immersion, it will be seen that one of the chief merits of the curve is that it keeps its greatest angle and least horizontal thickness of plating safely submerged at a considerable depth below the water line, where shot cannot strike it; but where protection is most required, the curved shield gives the greatest thickness of plating, the most acute angle of incidence, and the largest angle of clearance, automatically adjusting the same as the vessel rolls.

A curved shield of two inches in thickness, presenting an angle of 13° at the water line, and a horizontal distance through the plating of 12·25″, would give double the resistance of a plane-sided shield of 4″ thickness presenting an angle of 27°, and having a horizontal distance through the metal of 8·66″, as the squares of these numbers would be 150 and 74·99, or a ratio of 2 to 1 in favor of the curve, omitting the advantage of the large angle of clearance afforded by the curve; which also applies to all the ratios.

(To be continued.)

Circulation of Solar Energy.—M. Duponchel calls attention to a work, printed in January, 1882, in which he stated that the actual facts of science in regard to the nature of light, heat, electricity and magnetism testify to the absolute conservation of the living force which is manifested under divers forms of motion. Many years ago he tried to explain how the compensations could be effected, which are necessary to maintain the energy, and how the heat which is emitted can return to the focus of departure, forming a closed current and a continuous circulation, analogous to that which results from the action of the heart upon the movements of the blood. The views which have lately been published by Siemens, have induced him to undertake a mathematical discussion of the question and to confirm the results of his theory by facts of observation.—*Rev. Scientif.*, Jan. 27, 1883. C.

ECONOMY OF COMPOUND ENGINES.

By William Dennis Marks,

Whitney Professor of Dynamical Engineering, University of Pennsylvania.

The limits of profitable expansion are quite narrow, without the necessity arising of making assumptions, which may or may not be true, as regards condensation and re-evaporation of the steam used, and this statement is quite true therefore as regards a perfect gas expanding according to Marriotte's law.

Leakage aside, Mr. Hill's experiments would seem to prove that in the foremost types of simple engines at least one-fifth of the heat of the steam used does not appear on the diagram either as work or as steam heat voided at end of expansion.

That a fair comparative test has ever been made between single and compound engines under the imperative condition as to proper load and steam pressure the writer thinks is doubtful, since compound engines are almost always given higher steam pressures and lighter comparative loads than single engines.

The advantage of the compound engine must lie in its lesser condensation alone, other things being equal, and this diminution of condensation must compensate for the increased quantity of machinery demanded before we begin to consider its superiority.

This point must be considered experimentally by a careful determination of the ratio of the actual to the indicated steam and heat.

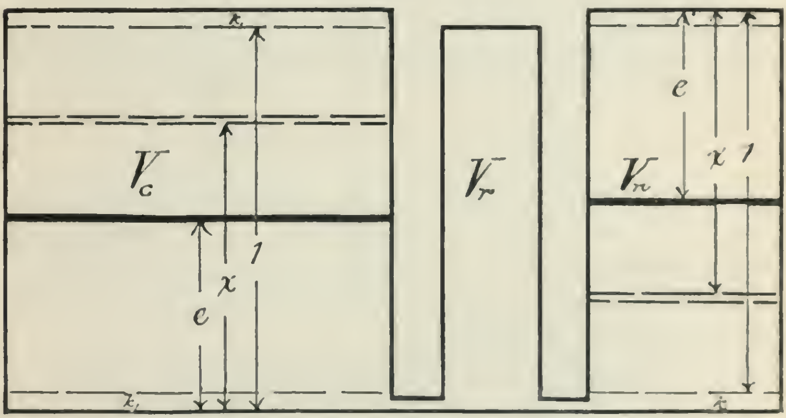
For the purpose of gaining a clear general, but not very exact idea, let us assume a perfect gas expanding according to Marriotte's law fed to a pair of compounded cylinders at a given initial pressure P_b and exhausted against a back pressure B outside of the cylinder. While these assumptions will not perfectly fulfill the conditions of steam, the results obtained will serve as a guide in the use of steam and by proper modifications can be applied to the steam engine itself. When steam is used the high initial temperature of the steam is communicated to the walls previously at or above the temperature of exhaust by means of the condensation of the steam which results in the water ready for re-evaporation at the instant of any diminution of pressure. That part of the cylinder walls subjected to initial steam being hotter than the expanded steam gives the steam this heat very readily which goes for the twofold purpose of recreating steam and of warming up to the

temperature of the steam the gradually uncovered walls of the cylinders which are at the temperature of the exhaust or perhaps above it.

These exchanges go on with a celerity not easily apprehended without thoughtful consideration of the great weight of iron in the steam cylinder and its conductivity for heat as compared with the relatively exceedingly small weight of steam and water at the temperature of evaporation which enter and leave the cylinder at each stroke.

Theories to the contrary, notwithstanding, it would it seem as if within the limits of economic expansion an equilateral hyperbola represents with quite as great approximation as any other curve the pressures of expanding steam in an iron cylinder steam-jacketed.

FIG. 1.



Taking then a perfect gas as our starting point. Assuming as the simplest case two cylinders with cranks 180 degrees apart

Let V_n = the true volume of the non-condensing cylinder (including one of its clearances k) up to its valve face.

Let V_r = the volume of the connecting channels (and receiver, if there is one) from valve face to valve face.

Let V_c = the true volume of the condensing cylinder (including one of its clearances k_1) up to its valve face.

Let e = the true cut-off of the non-condensing cylinder.

Let P_b = the initial pressure of the non-condensing cylinder. Pounds per square inch abs.

Let e_1 = the true cut-off of the condensing cylinder.

Let B = the back pressure of the condensing cylinder. Pounds per square inch abs.

After a compound engine has attained its regular work it has attained such a pressure P_r in the receiver (the word receiver will be used to comprise all pipes, steam-chest, etc., that may be between the two cylinders, whether there be a specially designed receiver or not) as will enable the condensing cylinder to void the same weight of vapor at each stroke as is received by the non-condensing cylinder at each stroke, and we can therefore write the equation

$$e\,P_b\;V_n = e_1\,P_r V_c$$

$$P_r = \frac{e\,P_b V_n}{e_1\,V_c} \qquad (1)$$

The pressure P_r is that occuring at the exact moment when the port to the non-condensing cylinder is closed, and when the piston head of V_c is at a distance e_1 from the beginning of its volume. (See Fig. 1.)

The absolute mean pressure pressing forward upon the non-condensing piston head can be written

$$e\,P_b\left[1 + \text{nat. log. } \frac{1}{e}\right] - P_b k \qquad (2)$$

At the moment of the closing of the steam port V_c the pressure P_r exists in all three divisions, pressing forward in V_c upon the piston pressing backward in V_n upon the piston.

The backward pressure upon the piston of V_n can now be calculated from the beginning of stroke to e_1.

$$P_r\left[(1-e_1+k)\;V_n + V_r + e_1\;V_c\right] = P_x\left[(1-x+k)\;V_n + V_r + x\;V_c\right]$$

Therefore the mean back pressure absolute upon the non-condensing piston, while the two pistons proceed in opposite directions through a fraction of the volume $(e_1 - k)$ is

$$\frac{P_r\left[(1-e_1+k)\;V_n + V_r + e_1\,V_c\right]}{(V_c - V_n)}\;\text{nat. log, }\frac{(1+k)\,V_n + V_r + (V_c - V_n)e_1}{(1+k)\,V_n + V_r + (V_c - V_n)k} \qquad (3)$$

This is also the forward pressure, absolute, upon the piston of the condensing cylinder.

When, now, the port of the condensing cylinder is closed, the two pressures part company, the back pressure in the non-condensing cylinder rising, and the vapor in the condensing cylinder expanding, and its pressure falling.

Let us consider first the back pressure in the non-condensing cylinder, while the piston moves through the fraction of the stroke $(1-e_1)$. We can write the following equation :

$$P_r\left[(1-e_1+k)\ V_n+V_r\right]=P_x\left[(1-x+k)\ V_n+V_r\right]$$

Therefore we have the mean absolute back pressure

$$\frac{P_r\left[(1-e_1+k)\ V_n+V_r\right]}{V_n}\text{ nat. log. }\frac{V_r+V_n(1+k-e_1)}{V_r+V_n\,k} \tag{4}$$

Secondly, the forward expansion pressure in the condensing cylinder, after its port to the receiver is closed.

We can write the following equation:

$$P_r\left[e_1\ V_c\right]=P_x\,x\,V_c$$

Therefore its absolute mean pressure is

$$e_1\,P_r\text{ nat. log. }\frac{1}{e_1} \tag{5}$$

Finally, if compression is used, the point at which compression begins being the fraction b of the volume of the condensing cylinder, we have

$$B\left[1-b\left(1-\text{ nat. log.}-\frac{b}{k_1}\right)\right] \tag{6}$$

We can now write the expressions for the mean effective pressure in each cylinder.

For the non-condensing cylinder we have, as the expression for the work done by it in one stroke

$$V_n\left\{e\,P_b\left[1+\text{ nat. log. }\frac{1}{e}\right]-P_b\,k-\frac{P_r\left[(1-e_1+k)\ V_n+V_r+e_1\,V_c\right]}{(V_c-V_n)}\right.$$

$$\text{nat. log. }\frac{(1+k)\ V_n+V_r+(V_c-V_n)\,e_1}{(1+k)\ V_n+V_r+(V_c-V_n)\,k}-\frac{P_r\left[(1-e_1+k)\,V_n+V_r\right.}{V_n}$$

$$\left.\text{nat. log. }\frac{V_r+V_n\,(1+k-e_1)}{V_r\times V_n\,k}\right\} \tag{7}$$

The expression for the work done by the condensing cylinder during one stroke is, if we assume $k=k_1$

$$V_c\left\{\frac{P_r\left[(1-e_1+k)\ V_n+V_r+e_1\ V_c\right]}{V_c-V_n}\text{ nat. log.}\right.$$

$$\frac{(1+k)\ V_n+V_r+(V_c-V_n)\,e_1}{(1+k)\ V_n+V_r+(V_c-V_n)\,k_1}+e_1\,P_r\text{ nat. log. }\frac{1}{e_1}$$

$$\left.-B\left[1-b\left(1-\text{ nat. log. }\frac{b}{k_1}\right)\right]\right\} \tag{8}$$

For example:

Let $P_b = 100$ pounds per square inch, absolute.
Let $V_n = 2$, $V_r = 1$ and $V_c = 8$.
Let the expansion be 8 times. We must then
Let $e = \frac{1}{2}$ and $e_1 = \frac{1}{2}$.
Let $k = \frac{1}{10}$ and $k_1 = \frac{1}{10}$ and $b = k_1$.
Let $B = 3$ pounds per square inch, absolute.

From equation (1) we have

$$P_r = \frac{100}{4} = 25 \text{ pounds per square inch.}$$

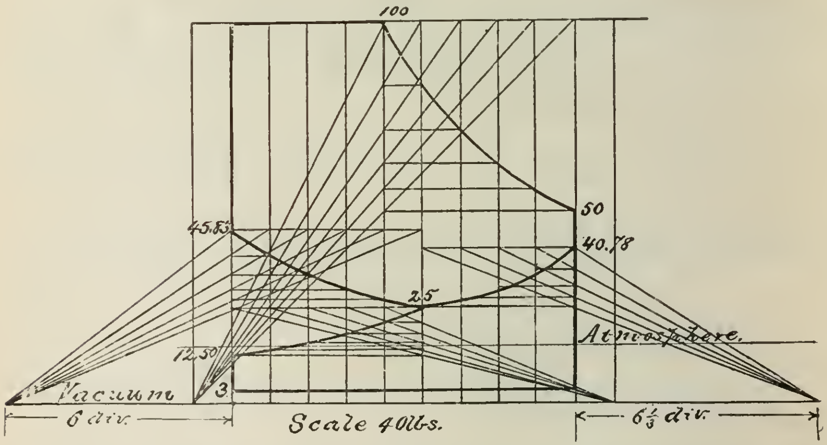
Equation (7) will then give

For the non-condensing cylinder $2\ \{84{\cdot}7 - 10 - 12{\cdot}63 - 14{\cdot}46\} = 95{\cdot}2$
For the condensing cylinder $8\ \{12{\cdot}63 + 8{\cdot}66 - 2{\cdot}7\} = 148{\cdot}7$

Total 243·9

These figures give the ratio of the horse-powers of the two cylinders. If we make V represent the area of the piston in square inches,

FIG. 2.



multiplied by the length of stroke plus clearance in feet, in formulas (7) and (8), we have at once the work done in one stroke by each cylinder from these formulas.

That is, in the formula for the horse-power

$$(\text{HP}) = \frac{PLAN}{33{,}000} \tag{9}$$

We have the product of the factors $P.L.A.$, and need only to multiply this by N (the number of strokes per minute) and to divide by 33,000 in order to obtain the indicated horse-power.

Fig. 2 represents the combined diagrams of non-condensing and condensing cylinders for the example laid down to the same scale, being a graphical solution of the problem already analytically solved for a perfect gas.

No explanation is given, as it is but an extended application of the ordinary method of laying down a true hyperbola on a diagram, and therefore familiar to all engineers.

A little trouble will enable a comparison of all the expansion curves of indicator diagrams from compound engines with the isothermal curve.

The mean effective pressures, as taken from the diagram, will be found to exceed the calculated pressures in the analytical solution, because the true volume of the cylinder exceeds the volume through which the piston sweeps by the amount of the clearance at one end.

This fact should be borne in mind in using the analytical method.

The ultimate expansion by pressures is

$$E = \frac{P_b}{e_1 P_r} = \frac{V_c}{e\,V_n} \qquad (10)$$

That is to say, it is theoretically quite independent of the volume of the receiver, as also of the point of cut-off in the condensing cylinder.

If we fix the ultimate expansion E of the steam and the point of cut-off in the non-condensing cylinder we at once determine the ratio R of the volumes of the two cylinders

$$R = E_e = \frac{V_c}{V_n} \qquad (11)$$

In the problem stated already $E = 8$ and $e = \frac{1}{2}$

Therefore $$R = \frac{V_c}{V_n} = 4$$

This result is quite independent of any other considerations in the case of hyperbolic expansion.

* It would appear probable that an expansion greater than 8 to 10 is not commercially profitable in single engines in iron cylinders where steam is used, and condensed afterwards.

* See JOUR. FRANKLIN INST., Dec., 1883.

The English rarely exceed a ratio of volume R for the two cylinders greater than 4 and sometimes go as low as 2. We are obliged to look to them for precedents because of their practical monopoly of compound marine engine building for the United States.

Equation (11) becomes between these limits

$$e = \frac{R}{E} = \frac{2}{8} \text{ to } \frac{4}{8}$$

That is to say with the ratio of cylinders of from 2 to 4 and with the expansion limited to 8 times, the true cut-off in the non-condensing cylinder should vary between $\frac{1}{4}$ and $\frac{1}{2}$ only.

If we make $e = \frac{2}{3}$ for a plain slide valve and adhere to 8 expansions of the steam we have $R = 5\frac{1}{3}$.

If we make the cylinders of equal size the cut-off would be $\frac{1}{8}$ and the work could all be theoretically better done by one cylinder.

The question of whether or no the lesser variations of temperatures in the use of two cylinders results in greater economy of steam could be finally set at rest by a careful series of experiments on such an engine.

For a simple engine we have the following temperatures in the one cylinder which is worked for one stroke.

Temperature of the boiler down to.

Temperature of the terminal pressure down to.

Temperature of the condenser.

$$\text{in compounded cylinders.}\left\{\begin{array}{l}\text{non-condensing}\left\{\begin{array}{l}\text{Temperature of boiler down to}\\ \text{Temperature of terminal pressure.}\end{array}\right.\\ \\ \text{condensing.}\left\{\begin{array}{l}\text{Temperature of terminal pressure down to}\\ \text{Temperature of condenser.}\end{array}\right.\end{array}\right.$$

The same engine should be used for both experiments, care being taken to prevent the idle cylinder, which should not be disconnected, from having other than frictional resistance.

Where the net instead of the indicated horse-power is to be determined the idle cylinder must be disconnected.

The experiments should answer this question:

What ratio exists between the steam from boiler and the steam by indicator? First for the simple engine. Second for the compounded

cylinders. Also the same for heat units as shown above in tabulated results.

The engine to have the same piston speed, initial pressure and load in both cases.

We can assume that E the measure of the ultimate expansion is a controlling consideration as determining the economy in the use of steam. R is often fixed from precedent or may be determined by the limitations of the valve used.

By making the respective lengths of volume of the two cylinders (their diameters being the same) proportional to their power, the stresses will be equalized on the crank pins.

If, however, we assume, as is generally the case, that the strokes of the two cylinders are equal, that the highest safe pressure attainable will be used in the boilers, and that the ultimate expansion of the steam will not exceed 8 or 10 times, we have left for variation only the point of cut-off e of the non-condensing cylinder, the point of cut-off e_1 and the capacity of the receiver V_r and the relative capacities of the two cylinders.

If the receiver be considered it is obvious that the only result of increasing its proportions is to decrease the mean pressure of the steam against both pistons up to the point of cut-off e_1 of the condensing cylinder.

This will decrease the power of the condensing cylinder and increase the power of the non-condensing cylinder up to the point of cut-off e_1.

After steam is cut off in the non-condensing cylinder the back pressure is not so rapidly raised with a larger receiver which results in a further increase of the power of the non-condensing cylinder.

After steam is cut off in the condensing cylinder its power is in no wise affected by the size of the receiver as the pressure $P_r = \frac{eP_b}{e_1 R}$ depends on the initial pressure the ratio of the volumes of the two cylinders and their respective points of cut off.

This pressure P_r occurs when the steam is just being cut off from the condensing cylinder. Can also be written

$$P_r = \frac{P_b}{Ee_1}$$

We observe that when the capacity of the receiver is assumed very great the back pressure line of the non-condensing cylinder comes very

near being a straight line; and further, if we make e_1 equal to unity, the forward pressure line of the condensing cylinder comes near a straight line and $P_r = \frac{eP_b}{R}$

In the present case $P_r = \frac{100}{2 \times 4} = 12{\cdot}5$ pounds per square inch.

We then would have for formula (7) giving, with rude approximation, the power of non-condensing cylinder.

$$V_n \left\{ eP_b \left(1 + \text{nat. log.} \frac{1}{e}\right) - P_b k - (1-k)\frac{eP_b}{R} \right\}$$

$$= 2 \left\{ 84{\cdot}7 - 10 - 11{\cdot}2 \right\} = 127.$$

and for formula (8) giving power of condensing cylinder.

$$V_c \left\{ (1-k)\left[\frac{eP_b}{R} - B\right] \right\} = 8 \left\{ 0{\cdot}9\,(12\tfrac{1}{2} - 3) \right\} = 68{\cdot}40$$

If we wish, having assumed a certain ultimate expansion E and ratio of volumes of cylinder R to determine at what point the condensing cylinder must cut off in order to render the work for the steam or gas a maximum we must so arrange that the terminal pressure eP_b shall equal the pressure of the steam in the receiver at the moment of its admission, this would require

$$\frac{P_b}{Ee_1} = \frac{eP_b\,(k V_n + V_r)}{(1 - e_1 + k)\, V_n + V_r}$$

With a fixed volume of receiver we have

$$e_1 = \frac{(1+k)\, V_n + V_r}{V_n + Ee\,[k V_n + V_r]} \qquad (12)$$

Which would give for the example first taken

$$e_1 = 0{\cdot}47 \text{ it has been assumed at } \tfrac{1}{2},$$

which probably would be near enough, if we had no clearance in the condensing cylinder, any other point, be it earlier or later, would result in diminished total power from the engine.

If the clearance in the condensing cylinder be considerable, its opening will immediately result in a disturbance of the gradual downward expansion, so that in this case we had better write, neglecting the back pressure, B,

$$e_1 = \frac{(1 + k)\,V_n + V_r}{V_n + Ee\,[k\,V_n + k_1\,V_c + V_r]} \tag{13}$$

which would give for the example taken $e_1 = 0{\cdot}32$.

This point should be particularly noted as showing how great a loss of power can occur from large clearances in compound engines.

Fixing the point of cut-off $e_1 = \frac{1}{2}$ we have from eq. (13)

$$V_r = \frac{e_1[\,V_n\,Ee(k\,V_n + k_1\,V_c)](1 + k)\,V_n}{1 - Ee\;e_1} \tag{14}$$

or $V_r = -1{\cdot}2$ which is impossible.

That is to say the pressure of a receiver is always productive of a loss where two cylinders are worked together, regardless of its influence on the cut-off of the condensing cylinder, and it is entirely unnecessary when cranks are together, or 180 degrees apart.

Unfortunately we cannot suppress the clearances altogether, and therefore from (13) we have, assuming $V_r = o$,

$$e_1 = \frac{(1 + k)\,V_n}{V_n + Ee[k\,V_n + k_1\,V_c]}, \tag{15}$$

This would give, in the example, to cover the clearances alone.

$$e_1 = {\cdot}36.$$

There is nothing wonderful, nor does it involve any new principle to prove, experimentally, that an early cut-off in the condensing cylinder will obtain increase of work from a given quantity of steam or gas.

V_r will represent the volume of the connecting pipes, and require the use of formula (13) in actual practice.

Cranks of compound engines are placed at angles less than 180°, for convenience of handling engines which have no fly-wheel, or which have to be stopped and started, or reversed; this procedure requires the presence of a receiver or compression space, and converts the distances of the pistons into trigonometric functions, relatively to each other, but in no wise alters the principles involved.

The assumption of a receiver, and of exaggerated clearances, in the present case, was made with a view to future use in the discussion of cranks at right angles,* and also to show clearly why they are hurtful.

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*The writer hopes to discuss this case at length and with practical applications in the near future.

Perhaps a resumé of the method of procedure in proportioning compound engines, in the present case, may be useful.

The first point fixed upon is the number of ultimate expansions E, and this should be adhered to as a controlling consideration.

The second is to fix upon the ratio R of the volumes of the two cylinders, unless their powers must be equalized.

$$R = Ee.$$

We can then assume R and fix e, the point of cut-off in the non-condensing cylinder, or we can assume e and fix R from it.

$$R = \frac{V_c}{V_n},$$

The third is having reduced the receiver and clearances as much as is possible to fix e_1 from formula (13).

$$e_1 = \frac{(1 + k) V_n + V_r}{V_n + R[k V_n + k_1 V_c + V_r}.$$

This will prevent a drop at the beginning of the stroke of the condensing cylinder, and the consequent loss of efficiency of the steam or gas.

It will be seen that e_1 would be unity were it not for the clearances and receiver.

The fourth is to calculate the relative powers of the two cylinders with these values from formulas (7) and (8).

The fifth is, when desired, to equalize the power of the cylinders for equal strokes, while still preserving the ultimate expansions E, the same, and without permitting a drop in the pressure from the terminal non-condensing to the initial condensing cylinder.

The substitution of the value of e_1, given above, in equations (7) and (8), and equating them, would be the regular mathematical method, but this is impossible because of the complicated form of these transcendental equations. We can, however, derive a first approximation in the following manner:

Assume $V_r = 0$, $k = 0$, $k_1 = 0$, $B = 0$, and therefore $e_1 = 1$.

Equate equations (7) and (8), under these assumptions, we have then the following criterion in order to equalize the power of the cylinders.

$$\frac{2R}{R-1} = \frac{\log. 2{\cdot}7183\, E}{\log. R}, \text{ and for } E = 8 = \frac{1{\cdot}337380}{\log. R} \qquad (16)$$

Which must be fulfilled.

Let $R = 4$	we have	$1{\cdot}14 = 2{\cdot} +$.
Let $R = 3$		$-3 = 2{\cdot}82$.
Let $R = 2{\cdot}9$		$3{\cdot}05 = 2{\cdot}90$.
Let $R = 2{\cdot}8$		$3{\cdot}11 = 3{\cdot}$
Let $R = 2{\cdot}7$		$3{\cdot}18 = 3{\cdot}10$.
Let $R = 2{\cdot}6$		$3{\cdot}25 = 3{\cdot}22$.
Let $R = 2{\cdot}5$		$3{\cdot}33 = 3{\cdot}35$.

That is to say, under these assumptions, R lies between 2·5 and 2·6.

$$\text{We have } e = \frac{R}{E} = \frac{2\frac{1}{2}}{8} = \frac{5}{16} \text{ of the stroke.}$$

In order that the quantity of steam used per stroke shall be the same as in the examples already solved, we must have $e\,V_n = 1$ in the first case $= \frac{5}{16}\,V_n$. Therefore, $V_n = 3\frac{1}{5}$, and $V_c = R\,V_n = 8$ as before. Let $V_r = 1$,

$$e_1 = \frac{3{\cdot}52 + 1}{3{\cdot}2 + 2{\cdot}5[1{\cdot}12 + 1]} = 0{\cdot}53. \quad \text{See eq. (13).}$$

$$P_r = \frac{e P_b}{e_1 R} = 23{\cdot}5 \text{ lbs.}$$

Substituting in formulas (7) and (8) as before, we have, leaving clearances the same.

For the non-condensing cylinder $3{\cdot}2\,\{67{\cdot}8 - 10 - 12{\cdot}00 - 7{\cdot}79\} = 121{\cdot}6$ and

For the condensing cylinder $8\,\{12{\cdot}00 + 7{\cdot}76 - 2{\cdot}7\} = 136{\cdot}5$.

Had there been no back pressure B, and no clearances or receiver, the cylinders would have balanced, as it is the ratio R is still somewhat too great. The short time spent in obtaining these results tentatively is well spent, and costs nothing when compared with the inconvenience and loss that may arise, when it is for any reason desirable to make the powers of the cylinders equal. Another approximation will be sufficient provided it is not deemed that losses in the non-condensing cylinder and passages will reduce the power of the condensing cylinder sufficiently when steam is used.

When these points have been covered, we must determine the size of the non-condensing cylinder for the required horse-power.

Equation (9) gives us for the work done during one stroke,

$$33{\cdot}000\,\frac{(HP)}{N}$$

all of which quantities are predetermined by the designer. If therefore we let V_n equal the product of the stroke, plus clearance in feet by the area of the piston in square inches, we have

$$V_n = AL.$$

The mean effective pressure P, we have from eq. (7).

Fix the stroke in feet and we have the area of the piston in sq. inches.

$$A = \frac{33{\cdot}000(HP)}{PLN}$$

It is in improved methods of study and experiment that we must hope for advancement, rather than in the piling up of chaotic masses of more or less accurate, and almost always incomplete experimental work, only valuable for commercial purposes. One series of experiments on a compound engine, modelled after the method adopted by Mr. Hill, and carried out with equal care and skill, will give us a better basis than we have as yet for comparison with theoretical results, which we must use to guide us, knowing them not to be precise, but feeling them far more accurate than attempted generalizations from data which are in no wise comparable.

Philadelphia, November 20, 1883.

Cannons of Silk and Steel.—A German inventor proposes to wrap a steel tube with silk until a diameter is attained corresponding with the ballistic power which is required for the cannon. For any given diameter, silk possesses a tenacity as great as that of the best tempered steel, and has the advantage of a superior elasticity. After the tube has been bored, it is centred upon a lathe which turns with a great angular velocity. Above and parallel with the tube are arranged a number of spools of silk, which covers the surface in the form of a helix, by means of guides, without leaving any space between the threads. When the desired thickness has been obtained, the silk is coated with gutta-percha or hardened caoutchouc, in order to preserve it from air and dampness. The silk being a bad conductor of heat, the gun can be fired very often without getting hot, and it can be more easily managed, since its weight is only one-third as great as if it were all of steel.—*Les Mondes,* April 21, 1883. C.

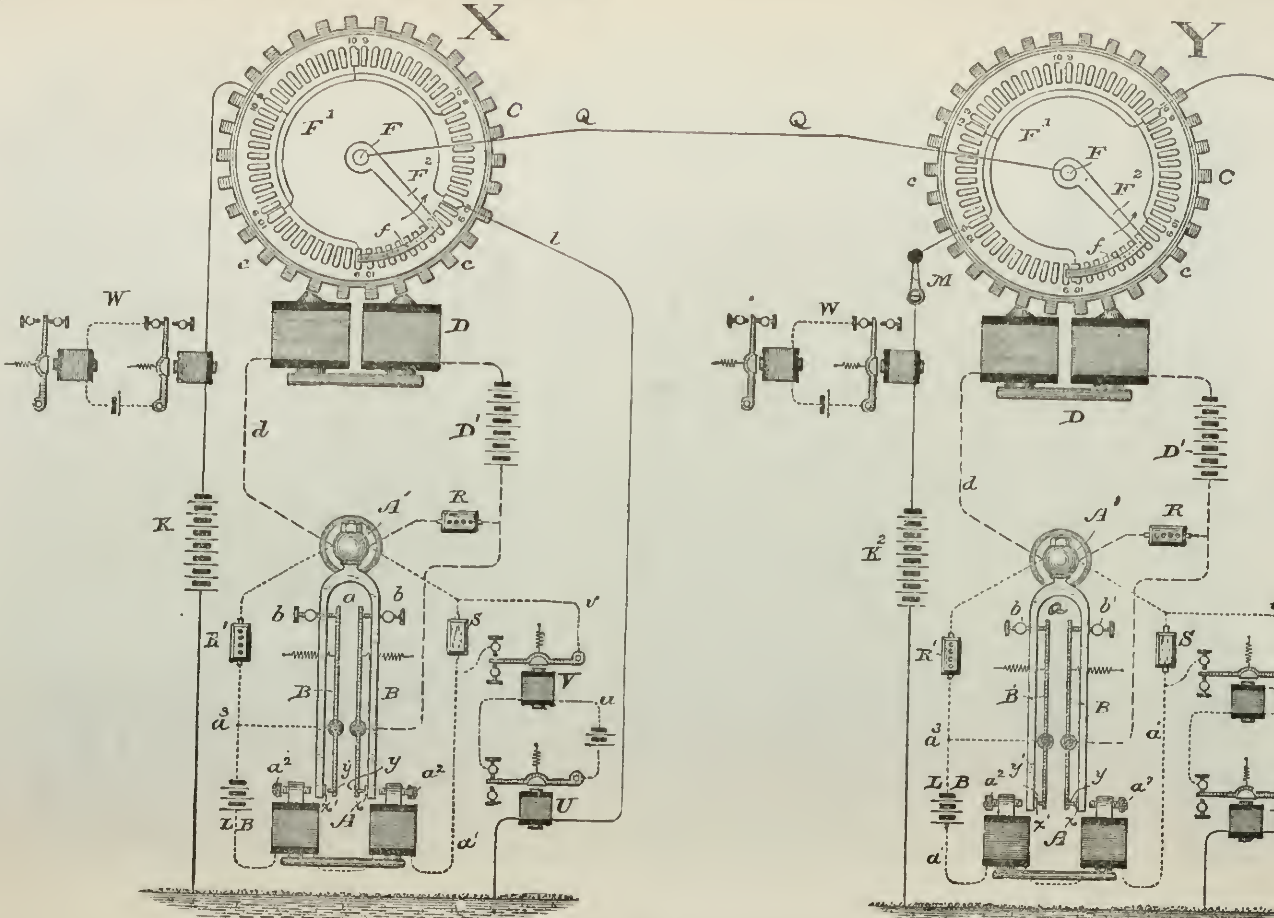


Fig. 1.

THE DELANY SYNCRONOUS-MULTIPLEX SYSTEM OF TELEGRAPHY.

By Prof. Edwin J. Houston.

[Read at the Stated Meeting, Wednesday, December 19, 1883.]

In this day of remarkable advance in electrical science, it is necessary for an invention to possess very unusual practical applications, and to display uncommon ingenuity or genius on the part of the inventor, to attract any more than transient attention or admiration on the part of the general public.

The successful laying of the Atlantic Cable, the commercial applications of electric illumination, and the actual transmission of telephonic dispatches, have very properly given to their inventors or promotors a world-wide reputation. The rapidity with which these inventions have followed one another, has led many to believe that but little new could reasonably be expected in the near future.

There has been, however, during the past two or three years, another inventor at work, who has at last completed, even to many minor details, an invention which, if we are not mistaken, bids fair to rival in importance anything that has hitherto been accomplished in electrical science; we refer to the system of synchronous-multiplex telegraphy, of Mr. Patrick B. Delany, of the city of New York.

Like other great inventions, that belong rather to eras than to individuals, the growth of the synchronous-multiplex system has not been entirely the product of any single mind; though in this particular instance, too much credit can scarcely be given to Mr. Delany, to whom the practical or working part of the system, is almost wholly due. Indeed, since this gentleman has introduced into the system the numerous details and separate inventions, without which its commercial application would be impossible, we may correctly speak of it as the Delany system.

The Delany synchronous-multiplex system is founded on the Phonic Wheel of Mr. Poul La Cour, of Copenhagen, who patented his invention in Great Britain, under Letters Patent, No. 1,983, of 1878.; and in the United States, as No. 203,423, of May 7, 1878.

Before proceeding to the description of the detailed apparatus of this remarkable invention, it will be best to first explain the nature of the work for which it is applicable, and to point out some of the more evident directions in which it may be practically employed.

The most evident commercial application of this system is its use for transmitting simultaneously, over a single wire, a great number of telegraphic dispatches, either in the same or in opposite directions.

Before the invention of the synchronous-multiplex system, the greatest number of messages that could be transmitted simultaneously over a single wire, as in the well-known quadruplex system, was four; and in this case the four messages were of necessity, sent in opposite directions; viz., two in one direction, and the remaining two in the opposite direction. In the synchronous-multiplex system, not only is the number of messages that can be transmitted greatly increased, but all such messages can be transmitted in one and the same direction; or any desired number sent in opposite directions. The great commercial importance of this feature of the invention will be at once recognized.

It may not be out of place to mention in this connection, as a confirmation of the importance of any system that will permit the simultaneous transmission of more than a single dispatch over the same wire, that it is a well-attested fact that the Western Union Telegraph Company has been enabled, to a very great extent, to practically control the telegraph business of the United States, by reason of its owning or controlling the only method heretofore known for successfully accomplishing this object.

Though we have mentioned the quadruplex as being the only system hitherto commercially employed for multiple transmission of dispatches, we have not forgotten the harmonic system of Mr. Gray. This, however, we believe, has not been commercially introduced to any considerable extent, owing to certain inherent difficulties attending its practical use.

Perhaps one of the most prominent features of the multiplex-synchronous system is its marked dissimilarity from either the quadruplex, or the harmonic systems already mentioned. The multiplex is a new departure in telegraphy, now practically realized for the first time.

As is well known to those acquainted with the principles of electro-magnetic telegraphy, the quadruplex system is based on the balancing or differential method, whereby the instrument of the transmitting operator, being unaffected by the signals he transmits, is thus left open for the reception of signals sent from the distant end of the line.

The synchronous-multiplex system, on the contrary, is based on the synchronous rotation of two discs, placed one at each end of the line,

by means of which a single wire, which constitutes the line, is simultaneously connected, at both of its ends, to corresponding operating instruments, and transferred from one set of instruments to another so rapidly that the operators, either sending or receiving, cannot realize that the line has been disconnected from their instruments and given to others, because each of them will always have the line ready for use, even at the highest rate of manipulation, and will, therefore, to all practical intents and purposes, have at his disposal a private wire between himself and the operator with whom he is in communication.

It will be seen, therefore, that in the synchronous-multiplex system, although more than one operator may be spoken of as simultaneously using the line at any given time, yet in point of fact no two operators are in reality absolutely using it at the same time; but that they follow one another at such short intervals, and the line is taken from one operator and transferred to another so rapidly, that none of them can at any time tell but that he has the line alone, and that therefore it is practically open for the use of every operator just as if he alone had control of it.

There will be practically established, by the use of a single line, as many private and separate lines as there are transferences of the line from the time it is taken from the first operator, and again given back to him.

This has, as we will hereafter point out, been extended in actual practice to as many as seventy-two distinct and separate circuits, maintained and operated on a single connecting wire.

It will be readily understood that the rapidity of transmission of each telegraphic dispatch will be necessarily diminished as the number of messages, that are simultaneously transmitted, is increased. This decrease in the rate of transmission, however, is far less than might be supposed necessary, as actual experience has abundantly demonstrated. For example, with the simultaneous use of six Morse telegraphic circuits, the most rapid rate of transmission attainable by the most expert operators is practicable; and with twelve Morse circuits, a rate of transmission is practicable as rapid as that generally employed by the ordinary operator; that is, by an operator whose rate of sending would be regarded as equal to that actually employed by the greatest number. It must not be supposed, however, that the use of the multiplex-synchronous system will be limited to the simultaneous transmission of twelve separate messages on one and the same wire, since certain con-

templated improvements will, it is confidently believed, greatly increase both the rate of transmission, and the extent of division of the line.

There have been actually applied to a single line, as we have already mentioned, as many as seventy-two separate and independent circuits. In this case the Morse instruments have been replaced by the ordinary printing telegraphic instruments, so that the messages are received and recorded on paper slips, in the well-known manner as practiced in the stock printing-instruments.

Although the rate of transmission, is, in the above case, considerably decreased, yet the adoption of a printing instrument is attended with many advantages that go far towards removing the slight inconveniences that result in actual commercial use. A printing instrument, as is well known, requires no special skill on the part of the one who operates it. Any one who can spell, can transmit a telegraphic dispatch, while no operator need be on hand for its reception, since the receiving instrument is entirely under the control of the person sending the dispatch. The necessity for skilled operators, at each end of the line, is therefore in a manner entirely done away with.

Three very considerable advantages are obtained by employing printing instruments, and thus doing away with the services of skilled operators for sending and receiving the dispatches viz.; economy, secrecy and an increase in the number of messages that can be sent during any given time.

The advantages on the score of economy and secrecy are manifest. Not only is the skill of an operator required at each end of a private line employing Morse instruments, but since private messages are to be transmitted thereon, integrity, as well as skill, is a prime essential, and both of these requisites must be paid for. On private lines, maintained by the use of the synchronous-multiplex system and printing instruments, no publicity is necessary, the interested parties only, sending and receiving the dispatches.

The advantages on the score of rapidity arising from no operator being needed at the receiving station, when printing instruments are employed on a private line, lie in the fact that the line being a private one, no time is lost in waiting for some other party that may be using it, nor in calling the party for whom the dispatch is designed, or in waiting for his return, during a temporary absence.

Taking all these facts into consideration, we think it will be found in actual practice, that the decrease in the rapidity of transmission,

consequent on the simultaneous employment of seventy-two separate circuits on one and the same line, is not sufficiently great to interfere to any marked degree with its commercial applications. In point of fact, with the system as it is now actually used, the rate of transmission is quite sufficient to enable each of the seventy-two subscribers or users of the line, to transmit, during, say the six hours that elapse between 10 A. M. and 4 P. M., the business hours of the day, no less than one hundred telegraphic dispatches of the ordinary length, an amount generally in excess of actual requirements of ordinary business, and, as a rule, quite in excess of any rate of service that could be reasonably expected on, the part of any of the telegraphic companies on which the general public are now dependent.

An advantage, however, of peculiar importance to the business public generally, that is possessed by the synchronous-multiplex system alone, is the readiness with which a single wire between any two subscribers connected therewith, can be increased in its capacity to meet the growing needs for an increased extent of division, or to meet some unforseen or unexpected emergency. Thus, suppose that one subscriber has a private line placed at his disposal between any two distant cities, and is furnished with what we may term one-seventy-second of the line; should his business increase, it would be a matter of simple connection of the transmitting and receiving instruments at the ends of the line to give him increased facilities for communication by placing at his disposal the one-thirty-sixth, or the one-eighteenth, and so increase his capacity for communication twice or four times respectively. In other systems, as is well known, this would need the erection of extra lines, and would necessitate the expenditure of both time and money, so that sudden and unexpected calls for increased facilities for business, which are liable to occur in times of financial crises, or of other great public excitement, could not be met.

A peculiar feature of the synchronous-multiplex system, that is not possessed by any other known telegraphic system, and that cannot fail to commend this system to the general public, is in its absolute secrecy. Unlike other systems, its lines cannot be secretly tapped and the messages intercepted, since, an ordinary instrument placed in a break in the line, would receive, in an utterly unintelligible form, not only all the signals being transmitted at the time, but also each of the separate makes and breaks in the continuity of the line circuit, while it is successively transferred from one operator to another, and these signals would be

so transposed and altered, that even if the instrument could record them, they would be as devoid of intelligent connection, as would the type, corrrectly set for numerous messages, and afterwards dropped through successive sieves from a height to the ground. This feature of absolute secrecy of the synchronous-multiplex system will, it is believed, prove of almost inestimable advantage to a government for the secret transmission of dispatches during war, or, in fact, at any time.

The successful operation of the synchronous-multiplex system is dependent on the maintenance of the synchronous movements of the rotating discs placed at the ends of the line. We will now proceed to describe the details of the very ingenious and beautiful contrivances whereby Mr. Delany has practically created a new system of telegraphy.

Fig. 1 represents a diagrammatic plan of two distant stations, say New York and Philadelphia, or Philadelphia and Chicago, represented by X and Y, respectively, electrically connected by the single line wire Q Q. The connections of the detailed apparatus required at both the transmitting and receiving stations are also shown in the figure.

In the following description the author has not hesitated to freely employ the language of the various patent specifications in all cases where he has deemed it advisable so to do.

An inspection of Fig. 1, will show that the apparatus at each end of the line, at the stations X and Y, is substantially identical. A steel fork a, at each station, is automatically and continuously vibrated by the action of the local battery L B, and the electro-magnet A. The circuit of the local battery is marked in the drawing a^1. The cores of the magnet A, which may be called the vibrator magnet, are prolonged in the direction of the free ends of the vibrating fork by the regulable screws a^2 of magnetic material, in the manner shown in the figure. The object of this adjustment of the extended magnet poles is to enable the said poles to be approached towards, or withdrawn from the tines of the vibrating fork, so as to regulate with great nicety, the rate of their vibration.

Platinum contacts x, x^1, are placed on the inner faces of the tines of the fork, and make and break contact with delicate platinum contact springs y, y^1, supported by adjustable insulated arms or levers B, B^1, pivoted on the bed-plate of the apparatus. The adjustment of these levers is secured by the thumb-screws b, b^1, against which they are drawn by the action of spiral springs. By these means the platinum

contact-springs y, y^1, are readily adjusted with great delicacy and firmness to the platinum contacts x, x^1, on the tines of the fork.

The circuit of the local battery $L\ B$, which is indicated in the drawing by the fine dotted lines, runs from the positive pole of the battery, through the coils of the vibrator magnet A, to the head of the fork, and through the contacts x^1, y^1, to the insulated lever B^1, from whence it passes back to the opposite pole of the battery. In order to prevent injurious sparking of the contacts x^1 and y^1, a resistance coil, R^1, is placed in a shunt circuit around them, extending from the point a^3, to the head of the fork, and to the insulated arm B^1, as shown.

The fork being mechanically started into a vibratory motion, will automatically make and break its local circuit, and thus send impulses into the fork-magnet A, that will continuously maintain the vibrations of the fork, in a well-known manner.

These movements, it will be observed have been maintained solely by the making and breaking of the contacts x^1, and y^1.

And now for the contacts x and y, which as we have seen, are placed in connection with the opposite tine of the fork. The making and breaking of these contacts, consequent on the fork's vibration, opens and closes the circuit of another local battery in which is placed an electro-magnet D, the function of which is to maintain the continuous rotation of the transmission apparatus C.

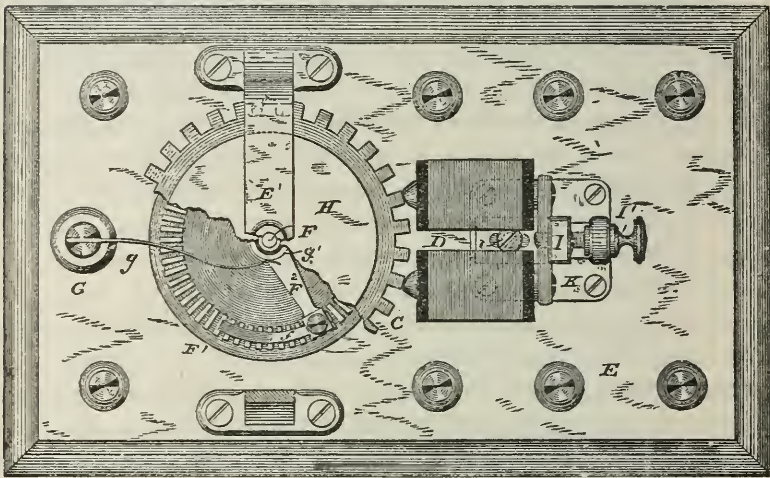
This circuit, which we will call the motor circuit, and which is indicated in the drawing by the larger dotted lines, passes from the positive pole of the motor-battery D^1, to the lever B, through the platinum contacts y and x, to the tine of the fork, to its head or support A^1, and thence through the wire d, to the coils of the motor magnet D, and back to the opposite pole of the battery. A resistance R, placed in a shunt between the head or support of the fork and the line of the lever B, prevents injurious sparking between the platinum contacts x, and y.

As the continuous vibration of the fork is automatically maintained by the local battery $L\ B$, as already explained, it will, at each vibration, make and break the contacts at x, and y, and thereby make and break the motor circuit. The alternate magnetization and demagnetization of the cores of the motor-magnet D, causes the rotation of the transmission apparatus C. The cores of the magnet D, have their faces shaped so as to conform to the circumference of the apparatus C, the teeth of which pass in close proximity to the faces of the curved magnet poles.

The motor-magnet and transmission wheel or disc C, provided with projections c, c, is the invention of Poul La Cour, already referred to, and is styled by him a "phonic wheel."

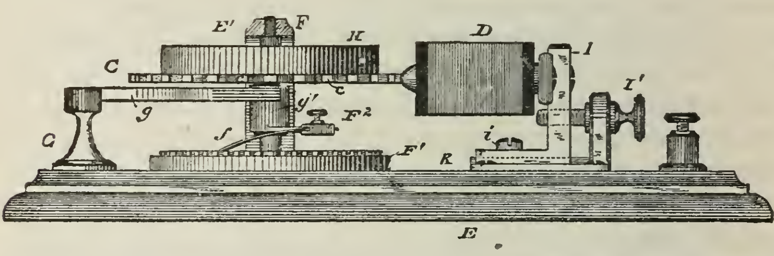
The transmission apparatus is illustrated in detail in Figs. 2 and 3. As we have already seen, it is an exact counterpart of the receiving

FIG. 2.



apparatus at the other end of the line. A base plate, E, provided with binding posts for electrical connections, carries a vertical rotary shaft F, that has its lower bearing in the bed plate, and its upper bear-

FIG. 3.



ing in a suitably supported bridge, E^1. A circular table, F^1, provided with a series of insulated contacts, is arranged symmetrically around the axis of rotation of the shaft. A radial arm, F^2, projects from the shaft, F, and carries at its outer extremity a socket and set screw, to which is attached a trailing contact finger, f. As the disc, C, is rotated

by the electro-magnet, *D*, the trailing contact, *f*, sweeps around the circular table, F^1, and is brought successively into contact with the insulated contact-pieces placed on the upper face of the table F^1.

The main line, *QQ*, has one of its ends connected with the trailing finger, *f*, through the radial arm, F^2, vertical shaft, *F*, contact spring-arm, *g*, and projecting post *G*. As the shaft *F* rotates, the line is therefore brought into successive electrical connection with the series of insulated contacts in the upper face of the table F^1. The toothed armature, or phonic wheel *C*, is securely keyed to the vertical shaft *F*, just above the hub g^1.

In order to equalize the speed of rotation of the apparatus, a cylindrical vase, *H*, of wood or other suitable material, filled with mercury, is attached to the face of the phonic wheel *C*, and rotates with it.

The cores of the motor magnet *D*, suitably supported by the standard *I*, can be readily adjusted towards or from the armature teeth on the phonic wheel *C* by the motion of a screw, I^1, which moves the standard, *I*, in an elongated guide slot, through which passes the screw bolt, *i*.

The cause of the synchronous rotation of the phonic wheel *C* is substantially as follows, viz.: Considering the action of a single pole of *D* when the wheel *C* is at rest, that one of its teeth or projections, *c*, that is nearest the pole of *D*, will be attracted towards it, and maintained in position nearest it, by the influence of the magnetic attraction of the pole of *D*; should, however, the phonic wheel be set into motion, with a velocity that shall cause a tooth, *c*, to pass the pole *D*, for each intermittent impulse in the battery circuit traversing the coils of *D*, the wheel will be maintained in a rotation, the speed of which will be regulated and controlled by the frequency of intermission of the battery current through the coils of *D*. That is to say, the speed of rotation of the phonic wheel *C*, and consequently the rapidity with which the successive contacts are reached by the trailing arm F^1, are regulated solely by the duration of the oscillation of the fork *a*.

FIG. 4.

FIG. 5.

FIG. 6.

The control which the intermission in the circuit traversing the coils of the electro-magnet *D*, exercises on the regularity of rotation of the phonic wheel *C*, will be better understood from an inspection of Figs. 4, 5 and 6.

Suppose that the central or axial line of the pole of the magnet c, is represented by the dash placed opposite c in the figure, and that r, indicates the centre of the phonic wheel C, whose direction of rotation is indicated by the arrow. Now, if during one impulse the central or axial line of one of the magnet teeth, c, on the phonic wheel, is moved from the point s to t it will be accelerated on its way from s to c, but retarded from c to t.

If then, as shown in Fig. 4, the acceleration and retardation are equal, the velocity of the wheel is unaffected by the impetus of the electro-magnet; but, should the wheel move slower, that is, lose in its motion, as shown in Fig. 5, then the acceleration, s, c, will increase, and the retardation, c, t, will decrease. Consequently, the electro-magnet D, will increase the velocity of the wheel in the same ratio that the wheel slows, or loses time.

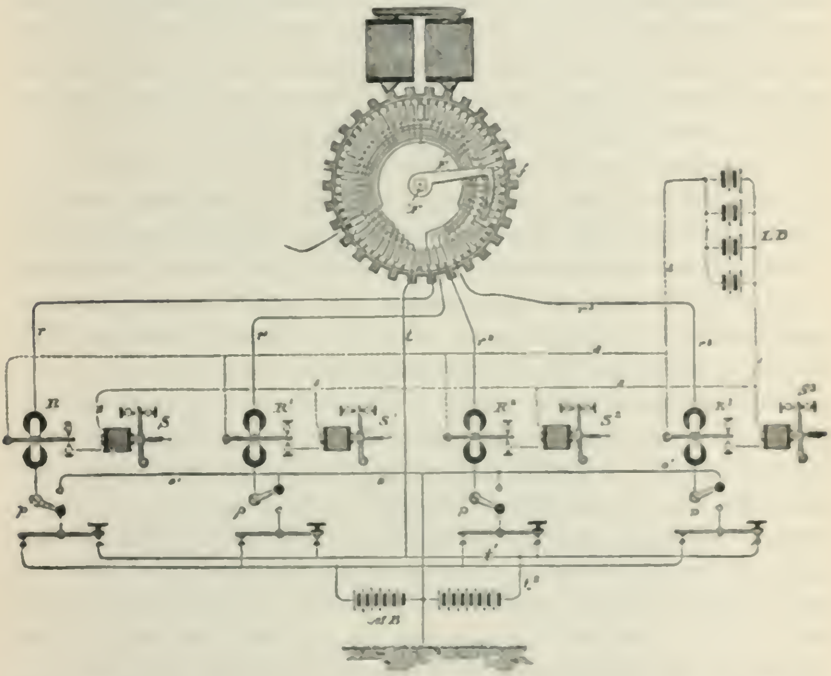
If, however, the wheel gains or increases in speed, as shown in Fig. 6, the acceleration s, c, will be decreased, and the retardation c, t, increased, so that the electro-magnet will have the opposite effect, and retard the wheel, in the same ratio that it tends to increase or go faster.

In the apparatus for transmission and reception, shown in connection with Fig. 1, which is substantially the same as that just described, the table of contacts F^1 is, for convenience of illustration, shown as placed above the armature disc C. In starting the disc C, an impulse of rotation is given to it somewhat in excess of the speed at which it will be maintained by the motor magnet, when, as the speed of rotation decreases, the armature teeth will come into proper relation with the poles of the magnet, and into the periods at which the makes and breaks occur in the circuit traversing its coils, when the disc will be continuously driven by the motor magnet. A suitable thumb piece, placed on the vertical axis F^1 serves to start the apparatus, an operation that is readily accomplished after very little practice.

Any suitable number of insulated contacts may be placed on the circular table F^1; sixty are shown in the figure. In practice these contacts are connected in accordance with the special number of circuits, which it is desired to simultaneously maintain on the same wire. In the special case shown in connection with Fig. 7, it is arranged so that four separate circuits shall be established on the same line wire. The sixty contacts are placed in six independent series, numbered from 1 to 10, consecutively. In the arrangement here shown, two of the contact pieces, in each series of ten, are connected in the same circuit, and

as there are six series, each of the circuits so connected will have twelve contacts for each rotation of the disc. An inspection of Fig. 7 will show that the 1's and the 5's in each series are all connected in one and the same circuit; the 2's and the 6's in another circuit; the 3's and the 7's in another circuit, and the 4's and the 8's in another circuit, thus providing four separate circuits in all. The contacts, therefore, from one to eight in each series, are apportioned among the four independent circuits, each of which will receive, for each revolution of the

FIG. 7.



trailing finger, twelve contacts and twelve electrical impulses, as will be afterwards described.

The detailed mechanism by means of which the separate and independent circuits so obtained are utilized for the transmission and reception of messages is shown in connection with Fig. 7. R, R^1, R^2 and R^3 are polarized relays, the function of which will be afterwards explained. S, S^1, S^2 and S^3 are ordinary Morse sounders, although in the practice of this invention some improvement has been introduced in connection with the instrument, the connections with the main and the local batteries, MB and LB, are clearly shown in the figure.

It will be noticed that the relay R, is connected by the wire r, with the contacts 1 and 5; R^1 is connected by r^1, with the contacts 2 and 6; R^2 by the wire r^2, with the contacts 3 and 7, and R^3 by the wire r^3, with the contacts 4 and 8. Similar instruments and circuits are placed at each end of the line.

Without further describing the operation of the instruments shown in Fig. 7, it need only now be borne in mind that the corresponding relays at the distant stations are connected with the correspondingly numbered contacts. When, therefore, the trailing contact finger at each station simultaneously touches the contacts bearing the same number, the corresponding instruments connected with these contacts at each station will be placed in communication over the main line, the trailing contact finger f, completing the connection of the main line with the contact arm in the manner already described.

If then the trailing fingers f, at each station, are maintained in synchronous rotation, they will pass regularly and simultaneously to the next contact, and successively over the similar contacts at each station.

During the time that the trailing contact fingers are on the correspondingly numbered contact pieces at each station, a complete and independent circuit, that has no connection whatever with the other circuits, is established between these stations.

Under the arrangement shown in Fig. 7, each of the four separate circuits will be placed in independent electrical connection with the main line, twelve times for each rotation of the distributing wheel C. Assuming the normal rate of vibration of the fork, at eighty-five vibrations per second, and that the distributing wheel C, is furnished with thirty armature teeth, or polar projections, the armature discs and trailing fingers will be rotated at the rate of two and five-sixths times per second, so that the corresponding instruments at the two stations will be placed in independent electrical communication with the main line, thirty-four times each second. This number of contacts per second will give to each set of operators a practically unbroken circuit, so that the operators at any two connected stations may communicate with each other, in either direction, as if they had a separate and independent line devoted entirely to their exclusive use.

We will now describe, in greater detail, the method adopted for transmitting and receiving the messages over any or all of the four circuits so provided. An inspection of Fig. 7 shows the relays, R, R^1, R^2 and R^3, connected with the series of contacts as described,

and the circuit completed from each relay, either to the ground through the line o^1, when the switches p, are placed as at R^1, and R^3, on their upper contacts, when the line is ready for receiving; or in connection with their lower contacts, as at R, and R^2, when the line is ready for transmitting.

The main battery MB, preferably split and grounded in the middle, has its positive pole connected with the back stops of the keys, and its negative pole with their front stops. The act of transmitting, therefore, sends into the line impulses of opposite polarity, and therefore permits the employment of the polarized relays. The local battery $L\ B$, is connected in multiple arc, in the manner clearly shown in the drawing.

Since each operator's circuit is made up of numerous rapid contacts with the main line, at the rate of thirty-four contacts per second, each of the ordinary Morse characters sent into the main line, is made up of more than a single contact, proportioned in number to the length of the character, the ordinary Morse relay could not be employed for the reception of these characters, since the numerous breaks comprised in each character would be recorded by the armature of the relay. In order to avoid this confusion, and to make the relays respond not to mere pulsations caused by the successive makes and breaks, but only to the reversals in polarity, caused by the connection of the split battery M, B, with the transmitting keys, the polarized relays R, R^1 R^2 and R^3, have been used in place of ordinary relays, so that the armatures of the polarized relays remain in the position that the last current has placed them, until reversal of the current changes their position, notwithstanding that the finer vibartions comprised in these reversals are continuously passing through the magnet of the polarized relay, but are not manifested on the armature. This feature of the invention is due to Mr. E. A. Calahan, the inventor of the gold and stock printing telegraph, and also the inventor of the American District Telegraph System, and who has been associated with Mr. Delany from the commencement of his investigations on the subject, and whose ability and great mechanical skill have very materially aided the full development of the system.

The prime essential for the successful application of the preceding system is undoubtedly the maintenance of the synchronous movements of the trailing arms over the contact pieces on the table F^3. This Mr. Delany has effected by an invention of marvelous beauty and ingenuity.

which is entirely automatic in its operation, and is so successful in practice, that the synchronism can be so perfectly maintained for days continuously without one instrument varying from the other the six-hundredth part of a second during that time. We will now proceed to an explanation of the comparatively simple means by which this practically absolute synchronism is maintained.

It has been shown, in connection with the description of the operation of the transmitting wheel, that its rate of motion is absolutely controlled by the rate of vibration of the fork, by means of which the successive impulses of the battery current through the motor-magnet are regulated.

Now it has been tried, but unsuccessfully, to obtain this synchronism by the mere mechanical adjustments of two forks, one at each end of the line; the forks being delicately tuned to exact unison with one another.

The many circumstances which produce slight variations in the rate of vibrations of a fork, have rendered it impossible to maintain, even in the same room, synchronism between two forks for more than a few minutes at a time, and this has only been possible by the most careful attention to the adjustments of the same. At distant stations, where the mere differences of temperature alone would, of necessity, produce sensible variations in the rates of motion of the two forks, the maintenance of even approximate synchronism would be practically impossible.

Mr. Delaney has completely overcome this hitherto insuperable obstacle to the successful adoption of any synchronous-multiplex system, by the happy invention of correcting impulses, that are automatically sent over the main line from one instrument to another, at such times only as the distant instrument is slightly in advance or behind the other instrument. These correcting impulses, that are thrown into the line only when needed, and of the necessity for which the instruments themselves, so to speak, are constituted the judges, are utilized for the purpose of slightly increasing or decreasing the rate of vibration of the distant fork, and consequently, the rate of rotation for the trailing arm at the distant station.

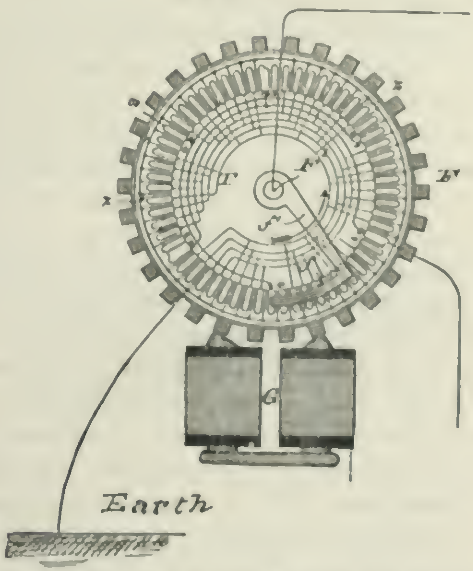
The manner it which these impulses are obtained when needed is as follows: It was probably remarked by the reader, that in speaking of the contacts in the plate F^1, no mention was made of the 9's and the 10's in any of the series, as having connection with any of the tele-

graphic instruments or circuits. It is the function of these contacts to maintain the synchronism of the apparatus.

Referring again to Fig. 1, it will be noticed that at one of the stations, as X, three of the 9's, that are the furthest removed from one another, that is three that are 120° distant from each other, are connected together, and to a battery K, one pole of which is connected to the ground; and that three of the 10's, that are likewise furthest removed from one another, are connected together and to a line l, leading to the correcting and regulating devices, which we will afterwards describe. The remaining three intermediate 9's and 10's are left open, that is, are not connected with any circuit.

At the other station Y, the 9's, corresponding with those connected with the battery at X, are left unconnected or open, while the alternate 9's, are connected with the battery K^2, one end of which is grounded,

Fig. 8.



while the 10's at Y, which are connected with one another and with the correcting devices through the line l^1, correspond with those which are unconnected with the station X, the remaining 10's, at Y, being unconnected at both stations; the three 10's, which are connected with the correcting devices through the lines l, and l^1, respectively, are extended or built out towards the adjoining 9's, that are unconnected with any circuit.

In order to provide room on the table F^1, for the expanded or extended 10's, without disturbing the symmetrical arrangement of the remaining contacts, the plates or contacts provided for the static discharge of the line, and which an inspection of Fig. 8, will show as located between each of the successive contacts of the circular table F^1, are omitted, and their place occupied by the extension of the expanded 10's, so that the space between the expanded 10's and the 9's which precede them, is the same as the spaces between the remaining contacts. Since the 9's preceding the extended 10's, and corresponding in position to the battery-connected 9's are open or disconnected, and since the static discharge plate between the 9's and the 10's at the distant end is retained, no bad results are experienced.

As long as the trailing contact-fingers are moving synchronously at both stations, that is, as long as they rest on correspondingly numbered contacts at the same moment, no occasion will exist for the correction of either apparatus; should, however, the instrument at Y, run a trifle faster than that at X, the trailing finger f, at station Y, will touch the extended side of a 10 contact, while the finger at X is still on a battery connected 9. An electrical impulse, consequently, will flow from the battery K, at station X, over the main line, and through the contact 10, at Y, and the line l^1, to the connecting device at that station.

A similar operation occurs if the apparatus at X, moves a trifle faster than that at Y.

As thus arranged the correcting impulses are retarding ones, since they are called into action only when the instrument at one or the other ends of the line, gains in speed slightly on the other. The inventor causes them to act as retarding impulses by employing them to cut a resistance out of the circuit of the vibrator battery. The effect of this is to increase the strength of the current traversing the coils of the electro-magnet A, and consequently its magnetic attraction for the tines of the fork. There thus results an increased amplitude of the forks' vibration, and a consequent lowering or decrease in the rapidity of its vibration. This retardation will of course affect the speed with which the transmission wheel is rotated, and consequently retard the rotation of the trailing finger.

The local circuit of the vibrator is shown in Fig. 1 as working generally through the adjustable resistances S. When, however, the apparatus at one station runs slightly in advance of that at the other sta-

tion, and a correcting impulse is consequently received through the main line and the line, l or l^1, the relay U, placed in that line, is energized, and its armature drawn from its back stop, thus breaking the local circuit u, and permitting the armature of a second electro-magnet V, to rapidly pass to its back stop, and thus complete a shunt circuit r, around the resistance S, so as to cut it out of the vibrator circuit. The consequent increase in the current strength of the vibrator circuit that is thus momentarily produced, momentarily retards the rate of vibration of the fork, and consequently slows the rotation of the trailing finger, and causes it to drop back on its proper contact. The operation is the same at both stations.

Whenever the operator at either station hears the stroke of the relay V, he knows that a correcting impulse has been received. By placing a relay and sounder W, in the circuit of the correcting battery, at each station, between the 9 contacts and the ground, he can also tell when a correcting impulse has been sent out. No difficulty will be experienced, therefore, in ascertaining which of the instruments is slightly in advance of the other, but as long as any ticks or sounds are heard on the instruments on the correcting circuits, the instruments will be found to be in synchronism, since the variations possible are confined to a limit not exceeding one-fifth of the width of any regular segment.

The apparatus is readily started by starting the fork and rotating the vertical shaft F, and the adjustment of the two apparatus is completed at the other station, Y. At that station the operator also starts his apparatus and closes the switches at M, and N. By the means already described the operator at Y, can tell which apparatus is running the faster, and he then proceeds to adjust his own apparatus, until he is aware of the synchronism of the two, by the tell-tale strokes at V, and W. It is found convenient in practice to make the resistance at S, in the shape of a box of resistances, so as to readily vary the amount of resistance normally included in the local circuit.

A very important and beautiful feature of this invention is found in the manner in which the correcting impulses are rendered effective when the relay U, leaves its back stop, as the corrections are thereby rendered practically instantaneous; whereas, if they were not made effective until the armature of the relay had been drawn to its front stop, the action of the correcting device, would be sluggish. The adjustment of the armature of the relay U, is very delicate, and it therefore, responds immediately to any correcting impulse: so, too, the

spring of the relay, V, is of sufficiently high tension to enable its armature to move almost instantaneously to its back stop.

Should the trailing arm at one station be moving more rapidly than that at the other station, it must soon overtake the trailing arm at the other station and bring them both into such relation to the battery connected 9's, and the extended correcting 10's, that the correcting impulses will thereafter maintain them in practical synchronism.

Should the main line between the two stations be accidentally broken, the synchronism would of course be destroyed, but on connecting it again, the instruments would of themselves, within two or three minutes at the most, again come into synchronism without the intervention of the operators.

The correcting impulses, we have described are retarding ones, and are only called into play, when one instrument runs faster than the other. Mr. Delaney has slightly modified his apparatus. so as to make the correcting impulses accelerating ones, that are only called into play when one instrument runs slower than the other.

In this connection it may be well to state that numerous devices by means of which synchronism can be obtained in connection with substantially the apparatus before described, have been discovered by Mr. Delany, and are fully protected.

We have described four sets of independent circuits simultaneously established on the same line. It is evident, however, that by increasing the speed of rotation, fewer contacts during a single rotation will suffice for the practical operation of the ordinary Morse circuits, or by increasing the number of contacts in the circle, a much greater number of circuits may be obtained, so that the subdivision of the line into a greater number of circuits may be effected, without diminishing the speed of working.

An essential feature of the invention, without which it cannot be practically operated for long distances, consists in separate contacts, as shown in Fig. 8, placed between the contacts on the table F^1, at each station, and connected together to the ground, so that the line, being put to the ground before each completion of the circuits, will be freed from the greater or less static charge, which is very apt to be present in all lines of any considerable length.

The synchronous-multiplex system, though as we have seen is somewhat complicated in its apparatus, is far simpler in its operation, and requires far less delicate adjustments than are essential in the quadru-

plex system. The difference between the two in this respect will the better appear, when it is known, that in the quadruplex system a change of electrical condition, equivalent to an increase in the length of the circuit of ten miles, is sufficient to throw it out of balance, and thus stop all communication; while in the synchronus-multiplex system, a change equivalent to five hundred miles may be instantly thrown on the synchronously operated wire, without destroying the synchronous rotation of the trailing arms, or interrupting the various circuits.

The possibilities that suggest themselves as naturally resulting from the solution that Mr. Delany has made of the problem of obtaining and maintaining, at distant stations, practically absolute synchronism, are, indeed, bewildering, and justly entitle this gentleman to a place among the world's great inventors.

Central High School, Philadelphia.
November 29, 1883.

Preservation of Paintings in the Parisian Opera House. — The paintings of M. Baudry, in the foyer of the Grand Opera House, have been greatly injured and almost obliterated by the smoke which escapes from the gas burners. The trouble might have been avoided if the arrangements of the lights had been more carefully studied. Each chandelier is composed of four clusters, each cluster having eight fan-shaped burners arranged symmetrically around the central support, and with a crown of eighteen jets placed above these burners. In consequence of this arrangement the strong ascending current of air, produced by the combustion in the lower clusters, agitates the jets of the upper crown and renders the combustion incomplete. The smoke which is thus produced deposits a thick layer of lampblack upon the paintings. M. Decaux, the subdirector of the dye-works at the Gobelins, proposes to change the arrangement of the chandeliers, so as to produce a complete combustion of the gas and rapidly remove the air charged with the products of combustion, of which the sulphurous acid is especially injurious to colors. The employment of the electric arc is impossible, because it fades the colors as effectually as sunlight. The incandescent electric light, as hitherto produced, has a tint which is too orange to give a good effect. — *Soc. d'Encour.*, Oct. 27, 1882.

Upper Limit of Audible Sounds.—E. Pauchon has tested the hypothesis of many physicists, that the upper limit of audibility of any given ear varies with the intensity of the sound. Using a Cagniard-Latour siren, he found that when the pressure of the steam, in the interior of the box, varies from 0·5 to 1·5 atmospheres, the limit of perceptibility corresponds to sounds which are comprised between 48,000 and 60,000 vibrations per second. On increasing the steam pressure to 2·5 atm., giving the discs a rotation of 600 turns per second, he could hear the sound of 72,000 vibrations, which was the sharpest that he was able to produce. He then vibrated, longitudinally, metallic rods fixed at one extremity, by rubbing them with rosined cloth. He found that the length of the rod which gives the limiting sound is, for any given metal, independent of the diameter. For steel, copper, and silver, the lengths are sensibly proportional to the velocity of sound in those metals. By using an ear trumpet the limit of perceptibility is slightly increased. If the rods are excited with different substances, such as rosin, turpentine, alcohol, ether, the limiting length changes and may vary from one to two. The sound which has ceased to be perceptible by the ear still acts powerfully upon a sensitive flame.—*Comptes Rendus*, April 9, 1883. C.

Protection from Boiler Explosions.—It has been noticed that boiler explosions are especially frequent in the morning. Take, for example, an engine which works during the day with steam at 6 atmospheres. The workmen leave the factory at 7 P. M.; about six o'clock the fireman reduces his fires and leaves the boiler with the gauge at 4 atmospheres. On returning the next morning, at 5h. 30m., he generally finds the gauge at 1·5 or 2 atm., with a fine water level. He profits by the reserved heat, which represents a certain expenditure of fuel; as an economist he utilizes it and drives his fires, to be ready for the return of the workmen, without suspecting the dangers concealed in the water which has been boiling all night. He does not feed his boilers, because they are at a good level. In other words, he prepares, unconsciously, the conditions which are most favorable to superheating and a consequent sudden and terrible explosion, which will be attributed to some mysterious and unknown cause. Trèves recommends that, before starting the fires in the morning, the fireman should restore to the water the air which it needs, by injecting it, with the aid of pumps and suitable tubes, into the lower portions of

the boiler. As soon as the gauge of the pump indicates a pressure which is superior to that of the remaining steam, all danger is removed ; the fires can then be driven, ebullition goes on normally and explosions become materially impossible.—*Comp. Rend.*, Ap. 9, 1883.

Mechanical and Physical Units.—The use of the kilogramme as a unit of weight has been so generally adopted that few would attempt to displace it, notwithstanding the inconvenience which results from the variations of weight with the place of the observer. A. Ledieu proposes to give it a fixed value by dividing it, in every calculation, by the ratio of the gravitating acceleration g of the place of observation to the gravitating acceleration g' of a place agreed upon, the pole for example. This mode of operation would take from the unit every characteristic of special nationality and would reduce every problem to the hypothesis of a dynamometer, with unalterable springs, gauged at the pole ; moreover masses and forces would be subjected to an identical correction. The ratio of g to g' varies from 1 to ·9949, for corresponding elevations above the level of the sea. If this ratio is overlooked, in experiments which are performed in different countries, errors of comparison may arise which are greater than the errors inherent in the copies of the standard of weight. Ledieu also makes valuable suggestions in regard to the units of time and space.—*Comp. Rendus*, April 9, 1883. C.

Color of Precious Stones.—Lt. Col. W. A. Ross, 1871, tried to obtain a blue color by dissolving pure alumina in a pearl of borax ; after a half-day's work he obtained a very pale-blue pearl, hard enough to scratch glass. This experiment led him to think that the blue color of sapphire is due to its 98 per cent of alumina, and not to the traces of any metallic oxide. In the following year experiments with lime which had been freshly calcined and with hydrated lime, showed a remarkable influence of the water upon the coloring, both of the flame and of the pearl. In 1873 he found that by dissolving pure alumina, under the blow-pipe, in a pearl of boric acid which had been opalized by means of platinum, and adding a small proportion of hydrate of potassium, he obtained a bluish pearl, much more rapidly and easily than by his first experiment. Some years later he bought, in London, a little American wavellite. On treating the powder of this mineral, under the blow-pipe, in an opalized or hydrated pearl of borax, with a

little hydrate of potash, he was astonished to see that his pearl became purple, then blue, and finally of a brilliant green. Subsequent experiments satisfied him that although phosphoric acid has not been discovered in sapphire or in lapis lazuli, it may have contributed to their coloring; for lazulite, which is similarly blue, is essentially a phosphate of aluminum, and pure phosphoric acid is well-known to be one of the most deliquescent substances in nature. The colors which can be produced by the aid of these three colorless substances, hydrated phosphate of aluminum, hydrated boric acid, and hydrate of potassium are —purple or amethyst, green, blue. Heintz has proved that the color of amethyst is not due to manganese or to titanic acid. Some chemists erroneously attribute the green color of the emerald to a trace of chromic acid; but chrome dissolved in the blow-pipe pearls invariably gives a pinkish hue.—*Ann. de Chem. et de Phys.*, Dec., 1882.

Chinese Telegraphs.—In 1862 Count de Lauture tried to simplify the Chinese language so that it could be used for telegraphing, but he was unable to solve all the difficulties of the problem. In 1866, M. Viguier experimented with autographic telegraphs, and proposed to employ a cipher code, by which the 44,000 Chinese characters could be transmitted by the Morse apparatus. This code was first published in 1870, when a cable was laid between Shanghai and Hong Kong. Every Chinese character is composed of two parts—one is called the *radical* or *key*, the other is phonetic. Every Chinese character can be classed under one of 214 radicals. In his first essay Viguier used three numbers to represent each character—that of the radical, that of the column under the radical and that of its order in the column. This system required the use of numbers varying from three to six ciphers, which rendered the transmission of despatches slow and difficult. By eliminating the characters which are rarely used, and employing those which occur in ordinary correspondence, he was able to simplify his system, so as never to require more than four figures for a single character. To this improved method he added Chase's system of holocryptic ciphers, so that messages can now be sent readily and with perfect secrecy.—*La Lum. Electr.*, Jan. 20, 1883. C.

Forgeable Brass.—A German journal gives this name to an alloy composed of 60 per cent. of copper, $38\frac{1}{2}$ per cent. of zinc, and $1\frac{1}{2}$ per cent. of iron. This alloy has the property of being readily worked

when warm. It can then be employed for constructing various pieces of lock work, which are commonly made of iron, and which, when made of this alloy, would be much less subject to rust.—*Chron. Industr.*, Jan. 14, 1883. C.

Selection of Seeds for Sugar Beets.—According to extensive observations by G. Marek, it is more economical to gather seeds from small than from large beets. There is a saving in land, in cultivation, in harvesting, and in the cost of storage, and the planting in the second year is accomplished much more cheaply and quickly. The seed development from small beets is limited to a small number of stalks, which grow higher and which show less disposition to bend. They produce heavier and brighter seeds, which ripen earlier. In the next planting these seeds produce beets which are rich in sugar and differ in no important point from those which spring from the seeds of larger beets.—*Dingler's Jour.*, Jan. 24, 1883. C.

Examinations of Sugar with Polarized Light.—P. Degener has made comparative experiments with the ordinary apparatus and the "half-shadow" apparatus of Schmidt and Häärsch. He regards the latter as of indisputable value, for persons who are affected with any degree of daltonism and for dark solutions. It may, therefore, be well recommended that manufacturers, who have occasion to investigate the production of sugar from molasses, should add the new apparatus to their other color apparatus.—*Dingler's Jour.*, Jan. 24, 1883.

Selenetropism.—Duchartre was led, by the influence which a light of very feeble intensity exercises upon helotropic movements, to vary the experiments by using moonlight. He sowed seeds of plants which were very sensitive to light, such as *Lens esculenta*, *Ervum lens*, *Vicia sativa*. When the plants were a few centimetres in length he put them in a dark place, where he kept them until the night of the experiment. The stalks became slender, long and white; the leaves developed slightly, with a light yellowish tinge. On three successive nights when the sky was exceptionally clear the plants were placed behind a large window with a southern exposure, so that they received the direct light of the moon from 9 P.M. to 3 A.M. From the very beginning of the exposure the stalks began to bend, so as constantly to present their concavity and the terminal leaf bud to the moon, following it in its course.—*Comptes Rendus*, March 5, 1883. C.

Protection of Water Pipes Against Rupture.—Messrs. Buxton and Ross attach a special valve to the extremity of a water pipe, which can be opened automatically by electricity. They connect with it a thermometer, which is so arranged as to close an electric circuit when the temperature approaches the freezing point. By the influence of the current a wedge is released which allows the valve to fall into place and open the emptying faucet.—*Chron. Industr.*, Jan. 14, 1883.

New Industry in Madrid.—In the neighborhood of the Puerta de Toledo, an establishment has been started for the manufacture of artificial whalebone, from the horns of black cattle and buffaloes. It is said that the factory is provided with all modern improvements, and that its products are already competing successfully with similar articles which are imported from abroad.—*Gaceta Industrial,* June 25, 1883. C.

CORRESPONDENCE.

Committee on Publication of the Journal of the Franklin Institute.

Gentlemen:—On page 471 (December, 1883), Prof. L. D'Auria submits a new proposition, *i. e.*, that the attraction is equal on all points of the level of a liquid mass surrounding any solid body, and bases his demonstration on the assumption (not clearly expressed in his letter, but inferable from the conclusion he reaches) that the principle of equal transmission of pressure in hydraulics is such that the pressure is equal on all points having equal normal distance from the surface.

I beg to refer the writer to "Theoretische Maschinenlehre," by Dr. F. Grashof, Leipzig, 1875. Chapter: Hydrostatics. The author defines: *Level-surface* within a fluid in equilibrium denotes any surface of such a character that the resulting force of all attractions is in all points normal to the same. Then he demonstrates that level-surfaces are also surfaces of equal pressure, . . . and that if the external pressure on all points of a free surface of a fluid is uniform, this surface must be a level-surface as defined.

The assumption in the correspondence referred to would therefore depend on the question whether or not all level-surfaces (surfaces of

equal pressure) are equidistant surfaces, for only in this case can the pressure be equal in all points having equal distance below the free surface of the fluid.

It is, however, easy to show that all level-surfaces in any fluid can be equidistant surfaces only if they are perfectly globular, *i. e.*, if the attracting body is a sphere composed of homogeneous spherical layers. Irregularities in the form or density of the attracting body will change the form of the level-surfaces so that they are no more equidistant, and hence the pressure is not uniform on all points having a uniform distance from the free surface of the fluid. This assertion is clearly though not directly expressed in the statement of Dr. Grashof: "Imagine lines drawn through a fluid, which intersect the level-surfaces at right angles, and which may be named lines of greatest change of pressure; then the resultant force of attraction in every point is tangential to the respective line of greatest change of pressure, directed in that sense in which the pressure increases, and the product of this force and the specific mass of the fluid is inversely proportional to the arc-element of the line in question enclosed between two level-surfaces of constant difference of pressure."

The intimation that these lines may be curves shows that the level-surfaces are not necessarily equidistant surfaces, and the final statement shows the attraction to be greatest where the distance between any two level-surfaces is least.

From the foregoing it would appear that the conclusion of your correspondent cannot be correct, being based on an erroneous assumption.

HUGO BILGRAM.

Philadelphia, Dec. 5, 1883.

Book Notices

GALVANOPLASTIC MANIPULATIONS: A Practical Guide for the Gold and Silver Electroplater and the Galvanoplastic Operator. By William H. Wahl, Ph. D. Philadelphia: Henry Carey Baird & Co., 1883. 8vo, 656 pp.

A practical work on the processes of electro-metallurgy cannot fail to be of interest to the general public as well as to the trade. It has been so long since any connected treatise has been written on this subject, that the general reader has looked in vain for any reliable source

of information concerning the later improvements in galvanoplastic processes. Indeed, so many improvements have been introduced into these processes that the old works are to a great extent worthless, and the need for a more modern treatise has been keenly felt. This want has, we think, been very happily filled by the work of Dr. Wahl, who has produced a book quite up to the present condition of the art.

The author logically begins with a brief statement of the historical facts connected with electro-metallurgy. He divides the general book into three parts, viz., Part I, Thin Metallic Deposits; Part II, Galvanoplastic Operations Proper, or Thick Metallic Deposits; and Part III, Chemical Products and Apparatus used in the Art.

Perhaps one of the most modern features of the work is its description of the applications of the modern dynamo-electric machine to the process of electro-plating. The advantages of these appliances, so fully appreciated by the trade, are here fully and clearly pointed out, and cuts and descriptions given of the principal dynamo-electric plating machines now in the market.

It is eminently proper that nickel-plating, which is an American industry, should receive at the hands of the author the very full and clear treatment he has given it, both from a historical standpoint and in its technical bearings. The discussion of the subject in both of these directions is very clear, and cannot fail to interest the general reader as well as the practical worker.

The process of electrotyping is treated in detail, and full descriptions given of various steps in this important branch of the subject. Illustrations are given of the machinery employed, which includes the modern improvements in this very important art. The process of stereotyping is also fully described. We note essential features of novelty in the chapters on tinning and galvanizing.

The treatment of Part III especially commends itself to the non-technical reader. The difficult subject of the chemical products used in electro-metallurgy are described in language so simple as to enable all to understand it. We note with pleasure the table of chemical names, with their equivalent or ordinary names, which cannot fail to be of value to the workman.

Valuable information of a practical character is given concerning the poisonous character of many of the chemicals employed and the proper antidotes therefor.

The lists of American and British patents connected with the sub-

ject of electro-metallurgy will prove of great value to the general student, affording as it does bibliographical information of a very extended character.

The work closes with an unusually full index. We feel sure that the general arrangement of the work, together with the clear and concise method of its treatment of its topical feature, will commend themselves very favorably to the public. E. J. H.

ELEVENTH BOOK OF SPECIMENS OF PRINTING TYPES, and every Requisite for Typographical Uses and Adornment. Philadelphia: MacKellar, Smiths & Jordan, Nos. 606–614 Sansom street.

THE AMERICAN PRINTER: A Manual of Typography, containing Practical Directions for Managing all Departments a Printing Office, as well as complete Instructions for Apprentices, etc. By Thomas MacKellar, Ph. D. Philadelphia: MacKellar, Smiths & Jordan. 1883.

In the ceaseless current of contributions to our shelves—yearly, monthly, weekly and daily—we have to note an arrival worthy of special mention; it embraces two volumes differing in size and tenor, yet closely allied in their intent and application, namely, a "Specimen of Printing Types" and affiliated Devices, and a text-book of the Art of Printing, styled "The American Printer."

The volume named first is an imposing quarto, bound most substantially and printed on finest paper in the best style of presswork. It is issued from the oldest establishment of the sort in the western hemisphere, and presents the authentic history of the Art in our half of the world.

Devoted, as our Library is, almost exclusively to Mechanics and Chemistry, any case of Fine Art needs a special ticket of admission, but the present case opens the door, and it stands confessed as the happiest union of the Useful and the Beautiful in our keeping.

The other volume is a neat duodecimo, also of faultless workmanship, and is the veritable text-book of the profession, addressing most pertinently at once the apprentice, journeyman and employer, in the language of respectful experience.

These volumes come to us by the courtesy of Messrs. MACKELLAR, SMITHS & JORDAN, of Philadelphia, who are worthy successors of most honored forerunners, among whom stands sturdy James Ronaldson, the first president of the Franklin Institute. H. O.

Explosive Materials. By P. E. Berthelot. Translated by Marcus Benjamin. To which is added a Short Historical Sketch of Gunpowder, from the German of Karl Braun. (Van Nostrand's Science Series.) New York: D. Van Nostrand. 12mo, pp. 180. 50 cents.

The first portion of this little book is a resumé of Prof. Berthelot's lectures on explosives before the College de France. After a somewhat detailed enumeration of the many objects to be accomplished by explosive materials, and a classification of these materials as strong and weak, rapid and slow, the force of explosives is considered. M. Berthelot states that this force may be calculated from a knowledge, 1st, of the chemical composition of the explosive; 2d, of the composition of the products of the explosion, to which must be added the quantity of heat given off during the reaction, the volume of the gases formed, and the rapidity with which the reaction takes place. A chapter on the origin of the reactions includes the sensibility of explosives, which is greatest when the explosive material is at the highest initial temperature.

The molecular rapidity of the reaction depends upon a coefficient which varies with the temperature, the pressure, and the relative proportions of the explosive mixture. The influence of the mass of the explosion operated upon is an important factor in the result. While capsules containing 15 mgrs. of fulminate will not explode in mass, if the quantity of fulminate be increased the case is different, and the explosion of one capsule is sufficient to explode not only all others in the same box, but all in the same locality. The rapidity of propagation of explosion varies directly with the pressure, and this brings the author to the consideration of his main point, and his own discovery, the explosive wave which is produced when the pressure produced by the explosion is sufficient to carry the reaction to succeeding particles with the velocity of sound. Explosions by influence are thus explained, but, according to Berthelot, it is not an atmospheric vibration which produces the explosion, but an ether wave. The statement is made that certain experiments demonstrated the propagation of detonation in a mixture of hydrogen and oxygen to take place at the rate of thousands of meters per second.

The Historical Sketch of Gunpowder is quite interesting. The greater part of it is derived from the ancient archives of Augsburg, which city claims the invention of powder by a Jew named Typsiles.

If the documents quoted be trustworthy, Augsburg employed cannon as early as 1372, and was acquainted with their use in 1371.

The book concludes with a very complete and valuable "Bibliography of Works on Explosives," which alone is worth more than the price of the book. W. H. G.

THE MATERIALS OF ENGINEERING, in three parts. Part II, Iron and Steel. By Robert H. Thurston, A. M., C. E., etc. New York: John Wiley & Son, 15 Astor Place, 1883.

The second volume of this work is devoted to the consideration of the manufacture, properties and uses of iron and steel. As introductory to the subject the qualities of metals in comparison with other materials are first discussed, and some account given of the general principles of metallurgy and the materials therein used. Chapter III considers the history of the manufacture of iron; points out its great antiquity—not less than 3,000 or 4,000 B. C.—and shows something of the state of the art among various primative peoples, tracing its development in later years, until the annual product of the iron and steel manufacturers of the United States alone was valued, in 1880, at $300,000,000.

The ores of iron are treated at length in Chapter IV, and their reduction and the manufacture of cast iron there fully considered.

Then follow, in course, descriptions of the various methods of making wrought iron and steel; and the remainder of the work devoted to a consideration of the chemical and physical properties of iron and steel; their strength, the conditions affecting their strength, and finally the subject of specifications is treated, examples given for various kinds of structures, with rules for testing and inspecting.

The work contains a vast amount of information, much of it of a very useful and practical character, and in an available form.

If the matter of the book is open to criticism, it is that certain portions of it are not so thorough or accurate as they appear to be and should be; for example, we note that the illustration which professes to show a steam hammer, such as is used for working puddle-balls, really represents a construction of hammer which is only used in small sizes, and never has been employed in any such work as that described. Again, we note that the cut illustrating the Sellers' Mechanical Puddler, shows a form of machine which it was found necessary to discard years ago, and if we recollect aright, the newer form was exhibited at the Centennial Exhibition.

These matters are not of much moment in themselves, and are only mentioned as a suggestion that the author has not in every case availed himself of the latest information obtainable. The only feature of the work to which we take decided exception is the absurd practice of giving quantities and dimensions in both English and French equivalents.

The book is written in English, and is presumably intended for the use of English speaking engineers and manufacturers; but there is no English speaking community which has adopted the exclusive use of the metric system, and there is not the least probability that there ever will be such a community.

Under these circumstances the constant insertion of parentheses such as those in following sentence: "The anvil is about 6 inches (15·24 centimetres) square, and 6 inches (15·24 centimetres) high," is needlessly annoying to the reader of the book. The present writer is at a loss to conceive of any good result attainable by this practice, which compensates in the slightest degree for the annoyance which it causes the reader, whose pleasure in reading the book is marred every moment by the interjection of these gratuitous translations which destroy the continuity of the sentence and interrupt the course of thought. There is, perhaps, no objection to giving the tabulated results of experiments in "kilograms per square centimetre," as well as in "pounds per square inch," because this enables us readily to compare these results with those of European observers, and if we do not wish to consider them so, it is easy enough to neglect that part of the table; but to translate every quantity that is mentioned in the text into its metric equivalent, results in taking up in many cases from three to five lines out of the thirty-eight, on each page, entirely in this manner. The author, however, is not always consistent, and we notice various places where important quantities are given in English equivalents only.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, December* 19, 1883.]

HALL OF THE INSTITUTE, Dec. 19, 1883.

The meeting was called to order at the usual hour, with Vice-President, Charles Bullock, in the chair.

There were present 128 members and 19 visitors.

The minutes of the last meeting were approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, December 12th, 1883, 27 persons had been elected to membership.

The presiding officer announced that he was ready to receive nominations for officers of the Institute to be elected at the annual election in January, 1884. The following members were thereupon placed in nomination, viz.:

For President (to serve one year), William P. Tatham.

" *Vice-President* (to serve three years), Chas. Bullock.

" *Secretary* (to serve one year), William H. Wahl.

" *Treasurer* (to serve one year), Samuel Sartain.

" *Managers* (to serve three years), Washington Jones, Joseph M. Wilson, Coleman, Sellers, C. Chabot, Pliny E. Chase, Dr. Isaac Norris, Theo. D. Rand, A. E. Outerbridge, Jr.

For Managers (to serve for two years), Hugo Bilgram, Charles J. Shain.

For Auditor (to serve three years), Lewis S. Ware.

" *Trustee in Pennsylvania Museum and School of Industrial Art* (to serve for one year), William H. Wahl.

The Special Committee on "Ordinance for the Examination of Steam Engineers," presented majority and minority reports, which were freely discussed by Messrs. Washington Jones, Coleman Sellers, Jr., William Helme, N. P. Williames, Wm. B. LeVan and J. W. Nystrom. On motion of Mr. LeVan, seconded by Mr. W. B. Cooper, the consideration of the reports was postponed until the next stated meeting.

On Mr. Nystrom's motion, seconded by Mr. LeVan, it was ordered that the reports be printed, and copies thereof placed at the service of members.

The Secretary's Report embraced a *resumé* of the progress of the work on the Electrical Exhibition; a description of Barnard's Adjustable Telephone Receiver, the principal feature of which is a double receiver, one for each ear, and so arranged upon a handle as to permit it to be readily fitted against the ears of heads of all sizes. The device frees the user of the telephone from the annoyance and distraction arising from local noises. Clark's portable Electric Gas-Lighter, shown on behalf of J. Chester Wilson, of Philadelphia, and consisting of a combination of an open circuit battery, and a Ruhmkorff coil

and circuit-breaker, the whole contained in a cylinder of convenient size to be held in the hand, and provided with a stem of any desired length, at the extremity of which a spark is passed between the poles of the apparatus, when the circuit-breaking mechanism is set in motion by the movement of a thumb-trigger in the handle, the latter continuing to vibrate long enough to cause a sufficient number of sparks to light the gas. The connections are so arranged as to pass under cover to the stem, the outer sheathing of the stem forming one side of the circuit, the other side being formed of a central rod within the hollow stem, and insulated from it. Near the end of the stem, and opposite certain openings in the hollow stem are the terminals of the circuit are brought near to each other, and insulated from each other by a plug of steatite. Across the face of the steatite plug the spark jumps, when the thumb-trigger of the circuit-breaker is sprung.

B. T. Loomis' improvement in Filters was also shown, on behalf of R. A. Hutchinson & Co., of Philadelphia. The same consists of a cylindrical chamber with perforated orifices above and below to admit and carry off the water, and divided into two chambers by a centrally located and perforated copper diaphragm, the perforations being fine enough to prevent the escape of the filtering material. This consists of granulated quartz in the upper chamber, and bone charcoal in the lower chamber. When filtering, the water is passed from above downwards through the filtering materials. When it is desired to clean the apparatus, the motion of the stream of water is reversed by a hand-lever controlling a suitably disposed cock, so that it enters below, and in passing up through the filtering material thoroughly agitates it, and discharges the arrested impurities through the washout pipe.

Mr. G. Morgan Eldridge then read a paper on "The British Patents, Designs and Trade-Marks Act of 1883, in its relation to American Inventors," which will appear in the JOURNAL.

Prof. E. J. Houston, after making some introductory remarks upon "The Delany Synchronous-Multiplex System of Telegraphy," introduced the inventor, Mr. P. B. Delany, of New York, who gave a lengthy account of his ingenious inventions, assisted by diagrams and lantern slides. Prof. Houston's paper on the subject appears in the JOURNAL for January. The presiding officer expressed the thanks of the meeting to Mr. Delany at the close of his remarks.

Adjourned.

WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVII. FEBRUARY, 1884. No. 2.

THE CHEAPEST POINT OF CUT-OFF.

By WILLIAM DENNIS MARKS,

Whitney Professor Dynamical Engineering, University of Pennsylvania.

In reply to the criticism of Professor De Volson Wood in this journal for January, 1844, in which he asserts that the proof given in my article on Cut-off, December, 1883, lacks in generality, and "is equivalent to assuming that the constant charges *vary* with the cost of steam," I would first express my regret that Professor Wood has not given some law, equation or example, instead of dealing in general assertions. It is easy to follow and criticise; it is hard to originate.

The assumptions on which my article is based are as follows:

First. That the constant charges are dependent solely on wages, cost of oil, interest, insurance, taxes and probable deterioration of machinery, and independent of all else.

Second. That the person designing an engine knows what horse-power is expected of it.

It is true that an engine does not run with exactly the same load at all times, but an engine is never designed or bought by an intelligent mechanic without some probable average horse-power being fixed upon.

These two are the sole assumptions made, and I do not see how the problem could be attacked with fewer fixed premises.

The constant charges C are not "assumed to be a constant fraction of

the cost of steam," but may be determined regardless of the cost of steam.

Whenever it is possible to fix the constant charges on and to design an engine regardless of its horse-power, then will the proof lack in generality. Until then, we cannot reduce the number of our premises below the two stated.

To take a homely instance, John Doe finds that the wages of his engineer and fireman, the amount of oil, and repairs, are about the same per day for a 100 horse-power engine as for a 300 horse-power engine. The taxes and insurance may be slightly less in one case, but surely not enough to make any great difference. John Doe has to pay this amount (say $10 per day), no matter how he varies the power of his engine or his cut-off.

Still John Doe has no use for more than 150 horse-power on an average; all over that would go to waste, if it did not work injury.

How is he to get this 150 horse-powers for the least sum of money? There is no other answer save this: *by using the least possible steam per horse-power per hour.* Reference to my paper will make it clear, I trust, as to how the point of cut-off affects the weight of steam per horse-power per hour, and also fix the limits within which physical laws confine the expansion of steam.

If John Doe should ever require 250 horse-powers in the development of his business, he would find it cheapest to add 100 horse-power by either putting in a new engine of the required power (250), so proportioned as to cut off at the cheapest point of cut-off, or, by adding a 100 horse-power engine to the one already in (both are assumed to have the cheapest point of cut-off), without increasing his working force.

This same point was mathematically stated in my letter of Oct. 20, 1883, to the *The American Engineer*, with the remark: "If I am correct in my premises, the method of Professor Rankine, as well as the papers of Messrs. Wolff, Denton and Weightman, and of Professor Thurston must be valueless." There has been no proof, of any practical value, given to the contrary of this assertion, or of my original position in this journal, June, 1880, save such limitations as I have myself established December, 1883. It is true that John Doe, when using 250 horse-powers, *gets his power* for less per horse-power than when using only 150 in this wise.

Reckoning steam at 25 cents per thousand pounds, and a horse-power at 25 pounds of steam per hour—

For 150 horse-powers.

Wages and constant charges per day	$10 00
150 × 10 × 25 = 37,500, at 25 cents	9 37
Total	$19 37

Cost per horse-power per day, $12\frac{11}{12}$ cents.

For 250 horse-powers.

Wages and other constant charges	$11 00
250 × 10 × 25 = 62,500, at 25 cents	15 62
Total	$26 62

Cost per horse-power per day, $10\frac{2}{3}$ cents.

In either case, John Doe's only opportunity to save money lies in saving steam per horse-power per hour, and the greater the power used the more money he can save by proper attention to the point of cut-off. It is right here that these gentlemen—Professors De Volson Wood and Thurston, and Messrs. Wolff, Denton and Weightman—have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded.

It will be noted that I have made a large allowance of $1 per day to cover the increase in constant charges due to the larger size of engine required for 250 horse-powers per day.

The business ability of John Doe will appear in his selection of an engine, and his hiring of attendants, and in the other details of constant expense.

In buying an engine he must have knowledge of the mechanical and physical action of steam, but his purchase and arrangements being made he has done with the constant charges, and must look to economy of steam as the only means of saving money.

In other words, John Doe must determine the most economical point of cut-off for his particular case from purely physical considerations, and then, if he can, buy an engine which will do his work with that cut-off with the least amount of constant charges.

He will be wiser if he anticipates an increase of business to choose a cut-off a little too early rather than too late for greatest economy.

The point of cut-off has, practically, nothing to do with the constant charges, save so far as it determines the volume of the cylinder required. The cost of an engine is not proportional to the size of the cylinder but rather to the amount of labor put upon it as a whole.

Suppose John Doe, finding out that he must pay $26.62, under the most favorable circumstances for 250 horse-power per day, thinks he can arrange matters so that the constant charges will be $10 per day and the cost of steam $16.62, he has got to make this difference in the constant charges in the difference that exists in the cost of oil, interest, insurance and taxes. This difference amounts to very little in reality. As for the difference in oil, its amount is so dependent on the care of the oiler more than anything else that it should properly not be considered.

If we assume $1,000 may be saved in buying an engine less economical of steam, we might save $100 per year, reckoning interest, taxes and insurance, as collectively 10 per cent, or $200 if at 20 per cent.

This assumption is improbable, but let us see what it means at 10 per cent. The reader can follow at 20 per cent. also.

One hundred dollars per year means 32 cents a day, and therefore if John Doe does save $1,000, he has just 32 cents to put into steam, or if he could manage to save $1 per day, he would have to reduce the first cost of his engine alone by about $3,000, but then the boilers must be larger in order to furnish 4,000 lbs. more of steam per day, with equal economy of fuel, to be used in the engine with less economy.

In reality no saving could be effected, and we can safely set off against any possible saving effected by diminishing the size of the steam cylinder, the greater cost of increase, logically required in the size of the boilers.

The question of high speed or slow speed has nothing to do with the point of cut-off, and often very little with the question of first cost. It is a matter in which sound mechanical judgment or experience must appear.

I have assumed John Doe to be a manufacturer, who wishes to do that thing which at the end of a year or ten years is most profitable, and not a person cramped for capital.

The difference in deterioration of engine and boilers is neglected and the wages of engineer and fireman are assumed to be the same in both cases. Deterioration practically depends far more on the care given than anything else.

In the case of an engine already erected, the owner naturally will

hesitate, however well informed he may be, before undertaking the trouble and expense of changing his engine until a considerable excess of its cheapest power is demanded of it, and from a financial point of view be right in disregarding, to a certain extent, the saving of steam.

In these matters there is always room for good judgment, but it should be borne in mind that fuel and steam from it are disappearing all the time, and that a saving of one dollars' worth of steam per day is equivalent to a saving in first cost of plant of from $1,500 to $3,000, and therefore we are financially as well as from a physical point of view justified in neglecting the constant charges, in determining the point of cut-off.

If the reader will refer to Hann & Gener, on the steam engine, page 115 (published London, Eng., 1854), he will there find the following equation

$$\frac{a}{c} = \frac{\text{volume at pressure } P}{\text{volume at pressure } P'}$$

which is derived from the formulæ of Pambour.

In this formula, if we assume the pressures inversely as volumes. the result is the same, as that given in my paper of June, 1880, by an original method and without knowledge of their method or results.

I may, however, lay claim to having originally shown the limitations of expansion to be dependent solely upon physical causes. [The "Limitations of the Steam Engine," JOURNAL FRANKLIN INSTITUTE, August, 1880, and "The Cheapest Point of Cut-off, December, 1883.]

Also to having shown the influence of clearance and compression upon the point of cut-off (JOURNAL FRANKLIN INSTITUTE, December, 1883), and the relation probably existing between the weight of steam from boiler and the weight of steam by indicator per horse power per hour (JOURNAL FRANKLIN INSTITUTE, January, 1884). I crave the readers pardon for prolixity in such simple matters, and for a self-assertion forced upon me.

With regard to equation (5) to which Prof. Wood has taken exception, I would say that e is a function of the mean effective pressure, is so written and so used, and that shrewd and skillful mathematicians have found no ambiguity in it.

To repeat again what I have said in this journal, Dec., 1883, C = the constant charges, in dollars and cents, and is assumed to remain a constant after once being fixed upon.

The proportion from which equation (5) is derived is this:

$cV : eV$ :: constant charges per day (C); cost of steam per day for a cut-off, e, and a given horse-power.

c is not a constant, as stated by Prof. Wood, nor is it said to be a constant in my paper; it is a function of the mean effective pressure.

If fallacy there be in what I have written, it must be found in the above proportion.

The question squarely at issue between myself and my critics is this:

Do the constant charges have the effect of making the cheapest point of cut-off later than it would appear to be from a purely physical consideration?

I have asserted, and believe I have proved, that they do not. I would further add that I am convinced that the ratio existing between the actual steam from boiler and the steam by the indicator diagram in no wise affects this question.

More knowledge of the law of this ratio may affect the point of cut-off, but will not involve the constant charges.

The mere assertion of so distinguished a mathematician as Prof. Wood carries so much weight that it is a duty which he owes to himself and to the writer to give the most careful consideration to the point at issue, and either prove the writer's error unmistakably, or to fairly acknowledge his own, in as public a manner as he has seen fit to publish his condemnation.

It is a question that not only involves himself, but also all his colleagues giving instruction in engineering in the Stevens Institute.

Since writing the above I have received an interesting letter from Mr. J. W. Thompson, of Salem, Ohio. His success as a practitioner has been so great as to render what he says of interest to all engineers, so I take the liberty of publishing his letter, in part:

Dear Sir:—We heartily agree with you that some reliable experimental data are badly needed to establish a reliable scale of "unindicated loss" for different points of cut-off, other things equal; but we regret to have to say that we are unable to contribute anything of value in that direction. We have long been aware that the "cheapest," or, as we would have put it, the most economical point of cut-off was considerably later than that at which the best results could be figured theoretically from the diagram; but just where the cheapest point is, all elements of cost, including interest on investment, being taken into the account, we are willing to humbly sit at the feet of any "Gamaliel" who can inform us. In the absence of any such positive knowledge we have been content to assume that about quarter cut with steam ranging from 75 to 90 pounds cannot be far wrong; at all events,

it is not too late, and if it is too early there is this compensation, that most customers will be far better satisfied if they discover that they have slightly too much power for the best economy than if they have not enough, and then almost everybody expects to increase their business in the near future, and would rather pay slightly too much per horse power at first than take the risk of soon being overloaded. Hence, for purely commercial reasons, there is no very urgent need for the coveted knowledge; we would not, probably, see any reason to depart from the "quarter cut" rule if we had it, except, perhaps, in cases where the duty was exactly known beforehand, and was subject to no fluctuations, and no possibility of future increase. Yet, for the sake of scientific satisfaction, and for practical use in the few cases where it could be applied, we would be much pleased to have the desired information.

From such data as can be obtained it appears that about the best that can be done under the best conditions hitherto existing when careful economic tests were being made, is to make the diagrams figure within near 80 per cent. of the actual consumption. And when such results are reached it is likely that it is due almost entirely to that unavoidable condensation of the induction steam in the cylinder by its recently refrigerated walls, a theory with which you are of course perfectly familiar. Condensation from radiation into the atmosphere can be so nearly prevented by non-conducting covering and loss from leakage can be so nearly prevented by good workmanship and attention to packing and adjustments, that the problem is reduced almost entirely to the question of inter-cylinder condensation—how much it is aggravated both absolutely and proportionately by high grades of expansion. Losses from the other causes named will not vary greatly with varying expansion, at least not proportionately, and perhaps not greatly absolutely. Hence, the more nearly the loss is confined to the unavoidable source when tests are being made, the more reliable will be the results with reference to the question under consideration.

There was formerly in our employ a young man, by name Jesse Warrington, who was something of a prodigy in the way of quick, instinctive and short-cut mathematics. Away back in the '70s, about 1874, if we mistake not, he suggested to the writer that there might be a constant figured out which, when divided by the product of the mean effective pressure and the volume of the total terminal pressure, would give the theoretical rate of water consumption, independently of any knowledge of the size and speed of the engine. Acting on the hint, I figured one out, it being obviously the consumption of water per indicated horse-power per hour of an engine subjected to one pound maximum efficient pressure, and driven by solid water instead of steam. The process was as follows: A horse-power being 33,000 foot-pounds per minute, it will be 23,760,000 inch-pounds per hour; this divided by 27.648, the number of cubic inches in a pound of water when a cubic foot weighs 62.5 pounds, gives 859,375, and I remember being somewhat struck with the singular fact that the calculation comes out exactly even, without a fraction. $\frac{33,000 \times 60 \times 62.5}{144}$ also gives it.

Yours truly,

J. W. Thompson (Buckeye Engine Co.).

The rule given by Mr. Thompson was mentioned as "the usual rule" in this journal, Jan., 1884, pages 1 to 5. I am pleased to be able to give the credit to its originator.

Several typographical errors occur in the formulæ in my papers in this journal, Dec., 1883, and Jan., 1884. These can be readily detected by the skilled mathematician.

On page 4, line 7, of this journal, Jan., 1884, "clearance included" should have read, clearance not included.

AN INVESTIGATION LOCATING THE STRONGEST OF THE BRONZES.

By W. Ernest H. Jobbins, M. E.

Triple Alloys of Copper, Zinc and Tin.

General Introduction.

It is thought better to preface this report upon the investigation, conducted by the author, with a short resumé of what had previously been accomplished by MM. Wertheim and Riche, Professor R. H. Thurston, and Mr. Maurice I. Coster.

These earlier investigations furnished the foundation for the present one, the author commencing at the point to which the others had brought the work. This report is, throughout, necessarily very concise; but the results indicate clearly where the strongest alloys will be found.

The subject has been divided into five parts; each one being a separate and distinct investigation, though at the same time an effort has been made to form a continuous report. Of course, Part V is the most important portion of this report, for the previous investigations have been reported and discussed a number of times, and it is to this part especially that attention is called.

It will be seen that the "strongest alloy" has been decided upon and that the area containing the best ground for future investigation has been reduced to a minimum; and, furthermore, the conclusions arrived at from the results of earlier work in this field are confirmed by the investigations here to be described.

Part I.

Researches of Wertheim and Riche.

The following is an abstract from a "Report on the Elasticity and Tenacity of the Alloys," by M. G. Wertheim.*

"In an earlier paper which I had the honor to present to the Academy during the session of July 18th, 1842, I considered the mechanical properties of the simple metals. After having examined and compared the different methods of studying elasticity in relation to ordinary as well as to high temperatures, I applied these methods to the pure metals and obtained results of which I will describe only those which serve as the basis of this new work.

"It was made known by these experiments: 1st. That the coefficient of elasticity is not constant for the same metal, but that it changes with density and in the same way. 2d. That longitudinal and transverse vibrations indicate a coefficient of elasticity a little greater than that deduced by direct elongation. 3d. That experiment agrees with theory as to the relation which should exist between the coefficient of elasticity and the mean distance between the molecules; that is, whenever, in the same metal, this distance becomes greater, the coefficient of elasticity diminishes, and reciprocally; consequently, the different metals form the same series, whether arranged according to their coefficients of elasticity or according to the proximity of their molecules. 4th. That the product of the coefficient of elasticity by the seventh power of the mean relative distances of the molecules is the same for the greater part of the metals.

"In this second paper, which I have the honor to present to the Academy, my object is to see, first, if these laws are equally applicable to alloys; then to ascertain whether the mechanical properties can assist us to an understanding of the arrangement of the molecules of the constituent metals of the alloys; and, finally, to seek for some relations between the properties of the alloys and those of the constituent metals. The alloys, with the exception of brass and of bell-metal, have not yet been studied as to their elasticity. The cohesion of the alloys, on the contrary, has been the object of a long series of experiments, especially by Muschenbroek and Karmarsh, but as yet, no general law has been found. The alloys which I have used in my

* *Comptes Rendus*, vol. 16, 1843, pp. 978–1000.

experiments have been made, in part, of the purest metals of commerce, and, in part, of the metals employed in my former researches. After mixing them well, I stirred them frequently while in fusion, then poured them. The ductile alloys were drawn, the others filed, to the requisite size. When the alloys were composed of metals whose specific weights were very different, or when they exhibited inequalities of color or of malleability, I made analyses of parts taken from the two extremities of the cast bar; consequently, with these analyses, I was obliged to reject a large number of non-homogeneous bars. My experiments were made upon fifty-four binary alloys and nine ternary alloys, among which are found, also, most of the alloys employed in the arts. These experiments gave the following results: 1st. If we suppose all the molecules of an alloy to be the same distance from one another, as seems natural, we find that the smaller the mean distance the greater is the coefficient of elasticity. We notice frequently some exceptions in the series of alloys, and further, the product of modulus of elasticity and the seventh power of the distance of the molecules, which is almost constant for simple metals, varies greatly in the alloys. It is possible that another hypothesis of the molecular arrangement will cause this objection to disappear. 2d. The coefficients of elasticity of the alloys agree sufficiently well with the mean of the coefficient of elasticity of the constituent metals, some alloys of zinc and copper being the only exceptions. The condensations and expansions which occur during the formation of the alloy do not sensibly affect the coefficient. We can thus calculate beforehand what should be the composition of an alloy, in order that it may have a given elasticity, or that it may conduct sound with a given rapidity, provided that this elasticity or this velocity fall within the limits of the values of these quantities for the known metals. 3d. Neither the tenacity, nor the limit of elasticity, nor the maximum elongation of an alloy can be determined, *a priori*, by means of the same quantities as determined for the metals which compose them. 4th. The alloys act like the simple metals as to longitudinal and transverse vibrations, as well as elongation."

The next paper of interest is one by M. Alfred Riche, which appears in the same publication seventeen years later, and in which he remarks: "There is no study more generally neglected than that of the metallic alloys. This very general neglect is due to the fact that the characteristics upon which we rely in determining the purity of substances are

usually inapplicable to these substances. Their melting points, even, cannot be determined, either because separation takes place before they attain their highest temperatures, or because we have no precise means for determining such high temperatures."

M. Riche then goes on to prove "that the crystalline form is not a gauge of their purity," and that the precise determination of the point of melting and of solidification is often prevented by liquation. It was this latter property that enabled M. Rudberg to prove the existence of true chemical combinations among the numerous alloys of the two metals; but it can only be utilized in a few cases where the point to be determined is that of the melting of alloys at low temperatures.

M. Riche does not give, in this paper, any information about either copper-tin or copper, zinc and tin alloys, confining himself to those of tin and lead, tin and bismuth, lead and bismuth, and antimony and lead. But, in a later paper, we find the following most valuable information relating to the alloys of copper and tin, with respect to their density, liquation and fusibility:

Density.—The first determinations were made on bars weighing from 50 to 60 grammes; but such great variations were found to exist in the texture of the different alloys, that, in subsequent investigations, the materials were reduced to powder. There were great variations in the expansion of the alloys; it increased quite regularly from those rich in tin up to the alloy $SnCu^2$, and attained a maximum when the tin and copper were in the relation of 1 : 3.

Liquation.—In order to exhibit this characteristic the material must be stirred at the moment of solidification, in order to separate the little drops of metal from the crystals already formed. The following table shows the results obtained on the last portion left liquid in a mass weighing 1,000 to 1,200 grammes. From this it will be seen that there is no appreciable liquation in the case of the alloys $SnCu^3$ and $SnCu^4$.

Fusibility.—In making this determination, the thermo-electric couple of platinum and palladium of M. Becquerel was used by M. Riche, Weber's needle being employed instead of the ordinary galvanometer, on account of its being much more sensitive. This apparatus was made by M. Ruhmkoff. It was found that the solidification of the alloys $SnCu^3$ and $SnCu^4$ took place at a temperature intermediate between the point of fusion of antimony and the boiling point of cadmium. Liquation prevents an exact result being obtained except with

TABLE I.—*Composition of Alloys.*

Formula of Alloy.	Calculated Weight of Tin.	Weight of Tin as Found.
Sn^5Cu	90·27	98·50
Sn^3Cu	84·79	96·99
Sn^2Cu	78·79	94·40
$SnCu$	65·01	82·83
$SnCu^2$	46·49	50·42
$SnCu^3$	37·37	37·29
$SnCu^4$	31·72	31·15
$SnCu^5$	27·09	27·76
$SnCu^6$	23·69	25·17
$SnCu^7$	19·98	24·85
$SnCu^8$	18·85	24·62
$SnCu^{10}$	15·67	21·50
$SnCu^{15}$	11·00	14·35

the alloys $SnCu^2$ and $SnCu^4$, in which the liquation is insensible. M. Riche says: "I stated, as Calvert and Johnson had previously shown, that copper and tin exhibit maximum contraction in the alloy, $SnCu^3$, contrary to the opinion of other experimenters who have maintained that contraction increases with the proportion of tin."* As M. Riche worked on alloys reduced to fine powders, and the other experimenters used ingot metal, there were differences between his figures and theirs.

In regard to the fusibility of metals which melt at high temperatures, M. Riche states that he has tried various methods of making this determination, and that the only one that can be practically applied is that of the thermo-electric pyrometer, formed by the junction of wires of platinum and palladium; but as I have not had the time to enter into this part of the work in my own investigation, I shall not stop to describe M. Riche's experiments. As for his results relating to the density of the alloys of copper and tin, they verify the known fact that copper and tin contract in uniting. Still, when the proportion of the tin is very high the reverse seems to take place, but the difference is very slight. It is an understood fact that the contrac-

* Briche, Traité de Chemie de M. Dumas, tome iii, p. 512.

tion is very slight and regular up to the alloy $SnCu^2$; that, from this point, it increases suddenly till it reaches a maximum, when the copper and tin are in the relation of 3:1. Beginning with the alloy $SnCu^3$, the density first diminishes and then increases quite regularly; but the density of the alloys richer in copper, as cannon bronze, is inferior to that of the alloy $SnCu^3$, which, however, contains only 61·79 per cent. of copper. While all the preceding have the grey line of tin, and while those that follow are white or yellow, this alone is distinguished by a bluish color. It exhibits no liquation, for after four successive fusions the last solidified product possessed the composition that it had immediately after the first casting. Consequently the alloy $SnCu^3$ is, in the series of alloys of copper and tin, what the alloy Ag^3Cu^4 is in the series of alloys of copper and of silver.* The hardness increases from tin to the alloy containing copper and tin in the relation of their equivalents. From this alloy up to that which corresponds to the formula $SnCu^5$ the metal is too brittle to be assayed.

PART II.

Research of Professor R. H. Thurston.

The following is a resumé of a part of the valuable work performed by Prof. R. H. Thurston as "Chairman of the Committee appointed by the U. S. Board appointed to test Iron, Steel and other metals," confining this second part of this paper to his study of the alloys of copper and tin.

In 1879 a "Report on a Preliminary Investigation of the Properties of the Copper-Tin Alloys" was made by the "committee appointed by the U. S. Board appointed to test Iron, Steel and other metals," Prof. R. H. Thurston, chairman. This committee determined the strength, ductility, resilience, and other mechanical properties of the alloys of copper-tin cast in the form of bars 28 inches long and 1 inch square in section, prepared from the best commercial metals, but without special precaution, ordinary care being taken only to obtain good castings; the intention having been to make a later study of pure alloys. It was desired to learn, besides the properties of each particular alloy, the laws which connected these properties with the proportions of the component metals, and also whether alloys mixed in the simple proportions of

* Annales de Chemie et de Phys., 3d série, tome xxxvi, p. 193.

the chemical equivalents of the component metals possessed any advantage over other mixtures. Two series of these alloys were made, the first consisting of twenty-nine bars, of which twenty-three were mixtures of the metals in atomic proportions, four were mixtures made without regard to the atomic proportions, and the remaining two were a bar of copper and a bar of tin each without admixture. The second series comprised twenty bars, ranging from 97·5 per cent. copper and 2·5 per cent. tin to 97.5 tin and 2·5 copper, with a regular difference of composition between consecutive bars of 5 per cent. In addition to these alloys, a few other bars of cast copper were made and one of cast tin. The metal for each bar was weighed with the greatest care in the Physical Laboratory of the Stevens Institute of Technology on a balance made by Messrs. Saxton & Bache for the U. S. Bureau of Weights and Measures. The metal weighed out for each bar was 4·5 kilogrammes and the weighing was made in all cases to within one-tenth of a gramme, the balance being sensible to a very much smaller weight. The error in weighing was less than 0·00005 of the whole. The principal observer was Mr. Wm. Kent. The bars were cast with equal care, in some cases being recast two or three times in order to obtain a perfect casting. Chemical analyses of these bars were made and a table was then formed showing the variation of weight occurring during the operation of casting. These pieces were then brought to the desired form and size and subjected to transverse stress, to tensile stress, to torsional stress, and finally to stress by compression.

From the results of these tests the following conclusions were arrived at: That the relation which the variation of composition bears to the percentage of copper and tin in the original mixture does not follow any regular law dependent upon the proportions of the metals. In general, there appears to be a greater loss of tin than of copper in the bars which contain the greater percentage of copper, and a greater loss of copper than of tin in the bars which contain the larger percentage of tin, and that the bars which contain about equal amounts of the two metals show great tendency to liquation.

In the alloys which contain less than 35 per cent. of tin by original mixture, there is a greater loss of tin than of copper, with but three exceptions. In the alloys containing more than 70 per cent. of tin there is a greater loss of copper than of tin, with only one exception. In all of the alloys of these two classes, the extreme variation, of a single analysis, from the original mixture is 3·6 per cent., and gene-

rally it is less than one per cent. In the alloys between these limits, or those containing between 35 and 70 per cent. of tin, there are some bars which show great liquation and others which show very little. The plotted curve at this portion of the series is consequently very irregular and fails to indicate any definite law. It only seems to show that, in these compositions, there is a great tendency to liquation, which may or may not take place, according as certain precautions are or are not observed in casting. In the bars of which analyses showed a great amount of liquation, it was uniformly the case that the upper part of the bar contained the larger percentage of copper, and from the appearance of the fractures of different portions, from the variations in hardness and in other properties, as well as from some analyses and determinations of densities made of different portions of the bar, it appears that there was a regular increase in percentage of copper from the bottom to the top, and that there was no distinct plane of separation between two different, but definite, compositions. In two cases the difference in composition of the top and bottom of the bar amounted to more than 20 per cent. In two cases there appeared to be lateral liquation, or separation of the metals in such a manner that the exterior of the bar contained a less amount of tin than the interior. The first of these (38·37 copper, 61·32 tin) contained, by original mixture, 39·20 copper, 60·80 tin.

The analyses of the turnings from the tension-pieces, from the top and from the bottom of the bar—the turnings being taken from the whole length of the cylindrical portions of the test-pieces, and including all of the metal in the square portion of the bar, except the cylinder in the centre, 0·798 inch in diameter—gave almost precisely the same results (43·36 copper, 56·40 tin), showing a loss of tin of more than 4 per cent. A piece from the middle of the bar was then analyzed, the whole of the square section being turned into chips. The analysis of this piece gave 38·37 copper, 61·32 tin, or 0·52 per cent. more tin than the original mixture. The other bar showed the same result. The original mixture was 34·95 copper, 65·05 tin, and the analyses of the turnings from the outside of the bars at top and bottom were 40·32 copper, 59·46 tin; 40·24 copper and 59·44 tin. The analysis of a piece from the middle of the bar gave 34·22 copper, 65·80 tin.

Specific Gravity.—There is a certain degree of regularity in the specific gravities, showing that the densities follow a definite law. The densities of the castings were much lower than those of the metals as

given by other authorities. The densities would have been higher had they been determined in the shape of fine powder or metal perfectly free from minute cavities. Those bars which gave less strength than might be expected from their composition, and whose resistances to stress are rejected from the table of averages, also had lower specific gravities than those metals of nearly similar compositions which had greater strength. From a comparison of the strength of the bars, containing less than 20 per cent. of tin, with their densities, it is apparent that the strength and density are in a certain degree dependent upon each other; that is, that the greater the density of an alloy of any given composition, containing less than 20 per cent. of tin, the greater the strength. This has been plainly shown in experiments by several authorities on gun-metal, which uniformly exhibits an increase of strength with an increase of density. This fact will also account for the much lower strength of the alloy 90 per cent. copper, 10 per cent. tin, and of metals of nearly similar composition, than is given by some authorities as the strength of gun-metal. It must be remembered that the casting of small bars, such as have been used in the experiments herein described, is especially unfavorable to the production of metal of great density, while in the casting of guns and of other large masses the pressure of molten metal is much greater, and all conditions favor the increase of density.

It appears probable that the actual specific gravities of all alloys containing less than 25 per cent. of tin, do not greatly vary from 8·95, and that the specific gravity of castings of these alloys will be less than 8·95 according to their degree of porosity. Riche gives figures showing the increase of density of several alloys by tempering and compression. The specific gravity of an alloy of 94 per cent. copper, 6 per cent. tin, was increased from 8·541 to 8·939 by repeated tempering and rolling. The specific gravity as determined from pieces of the castings, are more valuable than if they were determined only from turnings, for the reason that they show the cause of imperfections in strength and other qualities, and indicate that the proper method of improving the strength is to increase the density. They also indicate that the lower the specific gravity of one of the alloys, which shows a certain definite strength, the greater increase may probably be given to that strength by any means which will cause the specific gravity to approach the figures 8·95.

The several methods of increasing the specific gravity of these

alloys, and thereby increasing the strength, yet remain to be experimented upon. It is well known that rolling, hammering, or compressing the porous and ductile metals increases their density. Casting under pressure has the same effect, as is shown in the greater density of the bottom of a heavy gun casting than the top, or the sinking head, and, in a still more marked degree, by experiments which have recently been made of casting under heavy hydraulic pressure. It is probable also that temperature of pouring and rate of cooling have an important influence upon the density, and that the use of any fluxes which may remove occluded gases from the molten metal will be likely to increase the specific gravity.

The maximum density of the series is given by the alloy (composed of copper 62·31, tin 37·35, by analysis), the original mixture of which corresponded to the formula $SnCu^3$, and it is nearly approached by the alloy 62·42 copper, 37·48 tin. The figures are 8·970 and 8·956. The specific gravity of the same alloy, according to Calvert and Johnson, is 8·954. From the first of these to the end of the series, or, to pure tin, there is an almost perfectly regular decrease of specific gravity, that of tin being 7·293, which figure agrees with the results of several other authorities. From the regularity of this decrease of specific gravity, and from the fact that all the results between the alloy containing 62·31 copper, 37·35 tin, and pure tin agree closely with the figures given by other authorities for the specific gravities of the same alloys; it also appears that these alloys are much less apt to vary in their densities than those containing less than 25 per cent. of tin, and that they have but little, if any, porosity.

Comparison of Resistances.—By inspection of the curves of comparison of strength by tensile and torsional stress, it will be seen that the curves agree very closely. From the curves of tensional and torsional strengths, it is seen that the strengths of the alloys at the copper end of the series increase rapidly with the addition of tin, until about 4 per cent. of tin is reached. The further increase up to the alloy containing about 17½ per cent. of tin, is very irregular. As this irregularity corresponds to the irregularity in the same portion of the curve of specific gravity, it is probably due to porosity of the metal, and might possibly be removed by any means which would make the castings more compact. The maximum points of these two curves is reached at the same point, viz., at the alloy containing 82·70 copper, 17·34 tin. From the point of maximum strength, the curves drop very rapidly

to the alloys containing about 27·5 per cent. of tin, and then more slowly to 37·5 per cent., at which point the minimum, or nearly the minimum, strength of tin is reached. The alloys of minimum strength are found from 37·5 per cent. tin to 52·5 per cent. tin; the observations being somewhat irregular between these points, making it difficult to state the exact minimum points of the curve, but all agreeing in showing great weakness. The absolute minimum is probably about 45 per cent. tin. From 52·5 per cent. of tin to about 77·5 per cent. of tin, there is a rather slow and irregular increase in strength to the point which has been called the second maximum. From 77·5 per cent. tin to the end of the series, pure tin, the strength slowly and somewhat irregularly decreases. The second minimum being reached at the end of the curve. It will be noticed that the irregularity of the torsion curve is much less than that of the other curves, which is probably due to the fact that in the torsional tests, the time occupied in making the test was very uniform, and also that the torsional curve is made from the average results of, usually, four tests of each bar, while the tensile tests were but two in number from each bar. One of the most important facts to be learned from the curves is that all the alloys containing more than 25 per cent. tin are practically worthless for all purposes where strength is required, the average strength of these alloys being only about one-sixth of the average of those containing less than 25 per cent. of tin.

Comparison of Ductility.—The ductility follows a very regular law depending upon the composition. The ductility by torsional tests is determined from the extension of the exterior fibre or line of particles in a torsion-piece one inch long, in parts of an inch, which is calculated from the angle of torsion given by the autographic strain diagram. This gives a correct comparison of the relative ductility of all the pieces tested, whether very brittle, or very ductile. The maximum angle of torsion given is 556·75 degrees, which corresponds to an extension of 2·1975 inches of a line of particles, originally one inch long, on a cylinder $\frac{5}{8}$ inch in diameter, on the supposition that the diameter and length of the cylinder while being twisted remained unchanged. The minimum angle of torsion is 0·4 degree, which corresponds to an extension of only 0·000006 inch. The ductility of tin being therefore more than 200,000 times that of the most brittle alloy.

Total Resilience.—The resilience or amount of work done in breaking any specimen is measured in the same manner as mechanical work

of any kind, that is, by the product of a resistance into the distance through which the resistance acts. When the resistance is variable, the work is the product of the mean resistance into that distance. The work done in breaking a piece of metal by torsional stress is the mean resistance of the specimen, as measured by the mean ordinate of the autographic strain diagram, expressed in foot-pounds of torsional moment, or pounds acting at the radius of one foot multiplied by the distance through which this moment is exerted, as measured by the total abscissa of the diagram and reduced to feet, traversed by the resistance. The torsional resistance has been calculated from the area of the autographic strain-diagram in the manner above stated, the total resilience up to the breaking point being taken in each case and reduced to foot-pounds of work. The resilience bears a very close relation to the ductility. The maximum torsional resilience is given by a bar composed of 96·06 copper, 3·76 tin, which was one of the most ductile of the stronger alloys. From the bar which gave the maximum total resilience of 599·96 foot-pounds, there is a rapid decrease to the bar, 76·64 copper and 23·24 tin, which had a resilience of only 3·72 foot-pounds. From this bar to one containing 35·85 copper, 73·80 tin, all bars, with one exception, show a total resilience by torsion of less than one foot-pound each, the minimum being only 0·08 foot-pounds, or only about 0·0001333 part of the maximum. From this bar to that containing 0·32 copper, 99·46 tin, there is a gradual increase of the total resilience to 125·99 foot-pounds, which is the "second maximum" point of the curve.

Limit of Elasticity.—The limit of elasticity has been defined as the point at which the distortion begins to increase in a more rapidly increasing ratio than the force which causes the distortion. It corresponds nearly with the point of first appreciable set, or permanent distortion. In the autographic diagrams of torsional stress, it is the point at which the curve begins (usually suddenly) to change its direction and deflect towards the horizontal. We find that, in the stronger alloys, those containing less that 17·5 per cent. of tin, the elastic limit under torsional stress is reached at from about 35 to 40 per cent. of the breaking load. As the percentage of tin is increased beyond 17·5 per cent., the ratio of elastic limit to ultimate strength is increased, the alloy 76·64 copper, 23·24 tin, giving the ratio 100 per cent.; *i. e.*, the elastic limit was not reached until fracture took place. The same result is given by all the alloys from this point to that containing 38·87 cop-

per, 61·32 tin. From this point to pure tin, the elastic limit is reached before fracture. As we deal only with the results obtained by torsional tests it is not necessary to follow Prof. Thurston's researches further, as his moduli of elasticity were calculated from the deflections obtained in the transverse tests. It may simply be stated, in passing, that the figures and curves show great irregularity, but not greater than might have been expected.

The moduli of elasticity by the transverse stress, in the alloys containing less than 24 per cent. tin was about 14,000,000. From 25 per cent. to 35 per cent. it was about 15,641,866. From 35 to 75 per cent. there was a great irregularity, much greater than that of any other property. From the alloys containing 70 per cent. tin, to pure tin, the moduli again become a little more regular, but still vary very greatly, the tendency being to decrease as the tin increases.

Before passing to the consideration of the triple alloys, we will notice the work performed by M. Riche upon the copper zinc alloys; we shall then have the results of alloying copper and tin and copper and zinc and shall be in a better position to take up the subject of the copper, tin and zinc alloys.

Alloys of Copper and Zinc.—Says M. Riche: "The zinc which I used had been purified by two distillations in the laboratory of the 'Société de la Vieille Montague,' which generously placed it at my disposal. I undertook the study of the various physical properties of these bodies, as of copper and tin, but I was obliged to give up the examination of fusibility and liquation, because the place where I had specially prepared for this work, at the mint, was not left at my disposal. The hardness increases from the alloy 90 per cent. copper to that which contains equal weights of copper and of zinc, Zn Cu. The alloy $Zn^3\ Cu^2$ and the alloy Zn^2 Cu are extremely fragile and break at the first shock, and the others, containing more zinc, crack after a few blows. The density was determined, first, of some ingots weighing from 60 to 100 grammes, then, on account of the greatly differing texture of these alloys, filings of them were operated upon with the greatest possible care. But it is difficult even by a sustained vacuum, to eliminate all the bubbles of air, and I was afraid to heat the filings several times in water in order to secure the expulsion of the air, because water is attacked by zinc, and all the alloys rich in this metal; and, lastly, the volatility of zinc makes it difficult to prepare the alloys in exactly atomic proportions. We find that the contraction of the

two metals in these alloys is considerable from the second, $Zn^4\,Cu$, to the sixth, $Zn^2\,Cu^3$. It seems to be at its maximum in the neighborhood of the alloy $Zn^3\,Cu^2$, which is also remarkably like the preceding, in that it possesses none of the physical and mechanical properties which are utilized in the metals used in the arts. They are eminently crystalline and fragile, and appear to be in the series of these alloys what the alloys $Sn\,Cu^3$ and $Sn\,Cu^4$ are in the alloys of copper and tin. The theoretical density has been calculated with the number 7·20 found by me to be the average of four concordant determinations on metallic zinc."

Part III.

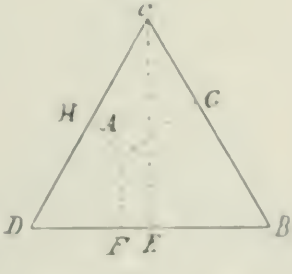
Thurston on Copper-Tin-Zinc Alloys.

We will now take up the work performed under the direction of Prof. Thurston, at the Stevens Institute of Technology, upon the triple alloys of copper, zinc and tin.

In performing this work Prof. Thurston was led to devise a method of planning this research and a system of recording data that has since led to the discovery of alloys of probably the maximum strength obtainable by any combination of the elements studied. The following is an abstract of the report:

In any equilateral triangle, *BCD*, Fig. 1, let fall perpendiculars

Fig. 1.



form the vertices to the opposite sides, as, for example, *CE*. From any point within the triangle, *A*, let fall perpendiculars *AG*, *AH*, *AF* and draw *AB*, *AC*, *AD*, to the vertices, thus obtaining three triangles, *ABD*, *ABC*, *ACD*; their sum is equal to the area of the whole figure *BCD*.

Now we have, since the triangle is equilateral, and $\frac{CE \times BD}{2} = \frac{AF \times BD}{2} + \frac{AG \times BC}{2} + \frac{AH \times CD}{2}$, $CE \times BD = (AF + AG + AH)\, BD$ and $CE = AF + AG + AH$, which are true wherever the point A may be situated; it is true for every point in the whole area BCD. Assuming the vertical CE to be divided into 100 parts, $AF + AH + AG = 100$, and these measure on this scale the relation of each of the altitudes of the small triangles to that of the large one. But we may now conceive the large triangle to represent a triple alloy of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and $BCD = 100$ per cent. or $CE = 100$ per cent., and the altitude of each small triangle measures the percentage of one of the three elements which enter that alloy which is identified by the point. Thus every possible alloy is represented by some one point in the triangle BCD, and every point represents and identifies a single alloy, and only that. The vertices B, C, D, in the case to be here considered, represent, respectively, copper = 100, tin = 100, zinc = 100.

Thus, having invented a method of studying all possible combinations, Prof. Thurston next prepared to examine this field of work

FIG. 2.

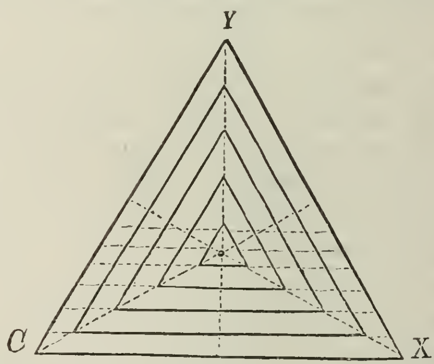


Fig. 2.

in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some

law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view the triangle laid down to represent this research was laid off into concentric triangles, Fig. 2, varying in altitude by an equal amount—10 per cent.—on which was laid out the proposed series of alloys.* These alloys were first all tested in the Autographic Recording Testing Machine, and their strain-diagrams were carefully studied. It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30 and zinc = 0, to the point copper = 40, tin = 0 and zinc = 60, were too soft or too brittle and weak to be of value.

(To be continued.)

Sensitive Thermometer.—M. Govi has presented to the Naples Academy of Sciences an ebonite thermometer supporting a capillary glass tube. This apparatus, when filled with mercury, does not show any slow elevation or diminution of temperature, but in rapid variations of heat a curious phenomenon is produced. If the temperature increases suddenly, the mercury descends in the tube and then slowly returns to the primitive level. The inverse phenomenon is produced in case of sudden cooling. The explanation is very simple, and depends upon the approximate equality of the coefficients of cubic dilatation in ebonite and mercury. When the increase of temperature is rapid, the recipient expands suddenly and alone, consequently there is a fall of the mercury in the capillary tube. The ebonite, being a bad conductor, transmits the heat only slowly to the mercury, which requires some time to resume its primitive level. A sudden impression of cold rapidly contracts the ebonite, which crowds the mercury into the capillary tube and thus raises the level. This experiment shows the importance of paying attention to the expansion of the recipient, in reading thermometric indications.—*Les Mondes*, March 17, 1883. C.

* For this table see Report by Prof. Thurston, read before the Amer. Soc. C. E., Jan. 5, 1881, p. 4, the Strongest of the Bronzes.

WATER-LINE DEFENCE AND GUN-SHIELDS FOR CRUISERS.

By N. B. Clark, Passed Assistant Engineer, U. S. N.

[From the Proceedings of the U. S. Naval Institute; revised and considerably enlarged by the author for publication in the Journal.]

(Concluded from page 36.)

At the instance of Chief Constructor Theodore D. Wilson, who appreciates the superior merits of the curved shield, the Honorable Secretary of the Navy caused a modified form of it to be adopted in the plans for the cruiser *Chicago.* The plans for the *Boston* and *Atlanta* still contain the plane-sided shield.

The flat, under-water, armored deck applied to the *Comus* class of the British navy is in no sense a deflecting shield, as it cannot be struck by shot, being intended merely to resist the more direct downward impact of the fragments of shell, exploding within the vessel, above it. The *Comus* deck has no more curve than is given an ordinary deck for drainage, and it is so far below the water line that it does not give the room under it for boilers and machinery, which the curve, rising above the water line, affords; and, for the same reason, it does not give the margin of buoyancy which would keep the ship afloat in the absence of water-excluding stores.

The plane shield is a foreign modification of the curve, having been applied to the *Leander* class of the British navy as late as 1880; while the curved shield is a domestic product, having been designed by the writer of this article more than twenty years ago, when serving in Farragut's squadron; and was the result of observation of the effect of shot on vessels in actual combat.

Figure 9 represents a cross section of a cruising vessel of 48 feet beam and 19 feet mean draught, in which the water-line is defended by means of the curved deflecting shield No. 2, heretofore described, in combination with water-tight compartments above it to be packed with coal or stores, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt to the vessel.

The cross section shown represents the compartments above the curved shield as packed with coal. The position of the curved shield in relation to the water-line is to be adjusted before going into action, by the admission of water to the double bottom. The cellular sides

of the vessel *BB*, between the curved shield *A* and the gun deck above it, are represented as packed with cotton, chemically prepared to resist fire, which would, by its elasticity, close shot holes and exclude water.

Figure 10 represents the curves of reserve and decreased buoyancy, for the purpose of showing that a vessel having a curved deflecting shield, rising slightly above the water-line amidships, and having water-tight compartments above it packed with coal or stores, covering and protecting the under-water body, could have the sides of the vessel above the shield completely open to the sea, without destroying her buoyancy.

Figure 11 represents a cross section of a cruiser fitted with a deflecting shield rising one foot above the water-line amidships, and attached to the sides four feet below it.

We will now suppose the sides of the vessel to be shot through, allowing water to enter into all of the compartments comprising the space *GTR* over the shield, in which water-tight compartments coal and stores are packed, capable of occupying three-fourths the volume. The water flowing in fills up the other fourth of the space *GWT*—which is interstitial—and when it has risen as high as the load water-line *WT*, the decreased buoyancy reaches a maximum equal to the weight of water filling one-fourth the space *WGT*, as shown on the curve by the ordinate *AO*. As the vessel sinks and the water continues rising in the life-belt of the ship—that is, the space above the water-line and the curved shield—the stores in the life-belt displace a volume of water equal to three-fourths the space above the load water-line and the curved shield; combining this increase of buoyancy with the decrease of buoyancy due to the water which has entered the space *WGT*, we obtain the curve *AD*, whose ordinate will represent the loss of buoyancy due to the entering water. As the vessel sinks, however, the curved shield is constantly increasing the displacement, and the ordinates of the curve *OB* will represent the increased buoyancy due to this increase of displacement. This curve intersects the former curve at *I*, at which point the upward and downward forces are again in equilibrium, and the abscissa corresponding to the ordinate at *I* will give the distance the vessel will sink by having her sides perforated completely above the shield, allowing water to enter freely all the compartments of the life-belt of the vessel. This abscissa is 2[illegible]", and

the vessel cannot sink further without the curved shield being pierced, allowing water to enter below it.

In comparing the plane shield, having inclined sides, with the curved shield, the relative structural strength of the two should not be lost sight of. In the curved shield, strengtened by curved beams and having the space over the shield and the berth deck divided by bulkheads, greater lateral and transverse strength can be given a ship than can be attained in any other way.

We will next consider the most desirable forms and arrangements for deflecting shields for guns. These are not simply shields, but are in fact armored gun-carriages, the guns being supported and trained upon them. Referring to Fig. 9, *C* represents a cross section of a vertical V gun-shield closed at the rear, with a 10½-inch wire wound pivot gun mounted on it *en barbette*. Fig. 12 represents a plain view of the same gun and shield.

This gun-shield is to be constructed of steel plates curved to the form shown on the plan view Fig. 12, and disposed vertically to deflect sidewise shot that come from the direction in which the gun is trained. The gun has no lateral motion of its own independent of the shield, consequently when the gun is trained to deliver its fire, the shield is at the same time trained to the most favorable position to deflect shot coming from that direction, the angle presented to the line of fire being very accute.

The gun is mounted by trunnions on a compact metal carriage, resting on slides bolted to the sides of the shield. The recoil is received on hydraulic buffers. The amount of recoil allowed for is three feet, which is ample. The top of the shield, except a space at the breech of the gun, is covered by plating of two inches thickness.

The vertical armor is formed of two thicknesses of steel plating; one enveloping the entire shield is of five inches thickness, and is reinforced at the forward end of the shield, where the angle is greatest, by an inner plating of three inches thickness. The two layers of plating form a shield of eight inches thickness, which at the acute angle presented will be impossible to penetrate with any gun now in use. These shields would be improved by constructing them of taper plates of single thickness, the greatest thickness being placed at the forward part of shield where the angle is greatest; thereby equalizing the resistance of the shield.

The shield and gun are mounted on a deflecting turn-table of eleven

feet eight inches, diamer, the outer edge of which is shaped like a double convex lens; the office of which is to protect deflectively the conical, anti-friction rollers upon which the shield rests. This lens-shaped turn-table is composed of two parts, being divided by a horizontal and a vertical line, as shown by *C* on the cross section drawing, Fig. 9.

The lower plate *D* of the deflecting turn-table is secured to the deck of the vessel, and in it are fixed the conical, anti-friction rollers upon which the shield rotates. The metal of the lower plate, immediately under the rollers, is cut away, in order to prevent an accumulation of sand or dirt which might clog them. The outer edge of the upper plate *F* embraces the lower plate *D*, thereby giving it a firm lateral support. So that no inordinate strain would be thrown upon the rotating pipe *E* by the rolling of the vessel, or the shield being struck by projectiles.

The lower plate *D* has a circular aperture in the centre through which rises the rotating and conduit pipe *E* from beneath the curved shield *A*, protecting the water-line.

The pipe *E* is secured to the upper plate *F* of the deflecting turn-table, which in turn is secured to, and forms a part of, the bottom of the shield. Consequently when the pipe *E* is turned, the shield and gun, on the deck above, are turned with it.

The shield and gun are trained by a pair of pneumatic engines *G*; pneumatic engines are preferred to steam on account of the exhaust exercising a cooling and ventilating influence. An endless screw on the shaft of the engines engages in a worm wheel secured to the end of the rotating pipe *E*, thereby turning the pipe, shield and gun in either direction with facility.

The pneumatic engines *G* are fitted with link-motion valve gear, with the lever *H* controlling it inside the shield, at the breech of the gun, convenient to the hand of the captain thereof, who trains the gun and shield by the lever without the intervention of any other person.

The lever is so arranged that when it is in the position *a*, the valves of the rotating engines are thrown into position to train the gun and shield in one direction; when in the position *b*, the valves are closed and the shield stationary, and when in the position *c*, the valves will be thrown open to train the gun and shield in the opposite direction.

This training apparatus has great power, there is therefore but little

danger of the shield being jammed fast by any obstruction. It will also hold the gun and shield firmly in any desired position, notwithstanding the rolling of the vessel.

Referring to Fig. 9, *I* represents a cross section of the pipe by which the shield is trained, which also serves as a conduit for ammunition into the shield. This pipe is V shaped, as shown by the cross section, the object being to present acute deflecting surfaces to projectiles which might strike it. It will be seen that in all positions of the shield and gun the conduit pipe *I* presents a constantly open passage to the magazines, beneath the curved shield, protecting the water-line.

The ammunition is passed up through the pipe *I* by means of the traveler *K*, which, in the drawing, shows a cartridge upon it; when it reaches the top of the pipe, inside the shield, it falls over into a little truck *L* ready to receive it. The traveler *K* is actuated by means of the crank *O*. The truck *L* is drawn out to the breech of the gun with the ammunition upon it, traversing the long arm of the lever *M*. The long and short arms of this lever are attached to a rock-shaft; the short arm is also attached to the connecting rod of a small hydraulic cylinder *N*, by means of which the ammunition is elevated to the breech of the gun upon the truck at the end of the long arm of the lever, as shown in the drawing. The loading lever *M* when in position to receive ammunition from the conduit pipe is upon the floor of the shield.

The space between the shield and the gun, when the latter is elevated is kept closed to exclude machine gun missiles, by means of the port stopper *P*, pivoted to the shield directly under the gun, against which it is pressed by means of the spring *Q*, or a counter-weight, thereby closing the space between the shield and gun occasioned by the elevation thereof.

These pivot gun-shields, while in action, should be kept trained so as to deflect projectiles even though the gun be not in use.

There is ample room in the pivot gun-shield for six men, while three men with the special appliances proposed can work the $10\frac{1}{2}''$ gun with facility and efficiency.

The total weight of the pivot gun-shield with the deflecting turntable, rotating pipe, rotating engines, elevating and loading apparatus, etc., is 65 tons and 20 pounds. But if the shield was made open at the rear it would weigh much less.

The weight could also be greatly decreased by making a shield of

less thickness of plating, which would still give a very efficient protection.

The plating of the shield, shown and described, is 8 inches thick, sufficient at the very acute angle presented, if constructed of homogeneous steel, combining hardness with toughness, to deflect projectiles from any gun in extence.

Figure 13 represents a plan view of a vertical V shield of the broadside battery, the gun being trained at right angles to the keel of the vessel. Fig. 14 represents a plan view of a similar vertical V shield, open at the rear, in which the gun is represented as being trained parallel with the side of the vessel. The cross-section of these V shield for broadside battery are represented by *RR* in the cross-section of the ship, Fig. 9. These V shields are mounted in bay-window like projections, which, however, do not extend beyond the line of the ship's side at the water-line, the vessel having considerable tumble home.

Broadside guns, mounted in this manner, can be trained so as to deliver fire almost directly ahead or astern.

These small V shields for the broad-side guns are trained in the same manner as the large pivot gun-shield, being fitted with the same appliances, and mounted on a deflecting turn-table of similar form, and in addition are pivotted in the *I* beams of the deck above. The guns, however, are not mounted *en barbette*, but extend directly through the shields.

It is proposed to partition off the upper part of the shield by means of metallic diaphragm, forming a compartment in the upper part for the accommodation of the gun-captain, who is to recline in a prone position; the diaphragm upon which he rests being well padded on each side to deaden concussion. From this position the gun-captain can see through the aperture *S* in the forward end of the shield, and can train his gun by means of the lever, controlling the valve gear of the rotating engines, beneath the curved shield. By the aid of these appliances three men, completely under cover, can load and fire a six-inch rifled gun with far greater rapidity and efficiency than a much larger number of men, exposed upon the open deck, working guns mounted in the ordinary manner.

In view of the great improvements recently made in machine guns of large size, firing percussion shell capable of piercing the sides of unarmored vessels at considerable ranges, it will be seen that a ship

having her gun-crews protected in shields of this form will possess an advantage so great that it would doubtless be good policy to have fewer guns, so protected, than a greater number unprotected. In other words, the weight of the battery should be divided between guns and gun-shields, the weight of ammunition remaining the same. The armor of the broadside gun-shields is four inches at the forward end where the angle is greatest, and two inches at the rear end where the angle is very acute.

The weight of the broadside gun-shields of four inches thickness of armor, with the deflecting turn-table, rotating pipe, rotating engines, elevating apparatus, etc., is 10 tons 760 pounds. But such a shield will give an efficient protection against the projectiles of heavy guns, while a shield of but little more than one-third the weight would give protection against heavy machine gun fire, as well as against splinters, fragments of shell, etc., which occasion nine-tenths of the casualties; a small proportion are due to exposure of men in the direct path of large projectiles. The form of the vertical V shields affords protection to the gunners within them against the side splash of splinters, and the spread of fragments of exploding shell, thus securing a great advantage over vertical armor, or guns mounted in a large casemate, as splinters and debris could devastate the interior of such a casemate from end to end, while light shields, which would offer no substantial resistance to heavy shot, would afford complete protection against splinters and fragments of shell; the protection abtained in this case against injury from shot by the subdivision of space being analogous to the protection afforded in the direction of buoyancy and stability, by the division of the underwater body into water-tight compartments.

Figure 15 represents a cross section elevation of a vertical V gun-shield, with an 8-inch rifled gun mounted on it *en barbette,* Fig. 16 is the plan view of the same. These figures illustrate the proposed method of mounting the pivot guns in the new cruising vessels. This shield is intended to be trained and the gun operated in the same manner as those heretofore described, being fitted with the same appliances; and they permit of the guns being fired either directly ahead or directly astern. As it is open at the rear end, it can be made of a proportionally less weight than the pivot gun-shield heretofore described. The plating is disposed in two layers; the outer one enveloping the entire shield is of three inches thickness, this is reinforced at the forward end, where the angle is greatest, by an inner plating of

two inches thickness, making a total thickness of five inches. The best method however for the construction of such shields would be by taper plates of single thickness.

The weight of this gun-shield with the deflecting turn-table, rotating engines, rotating pipes, loading apparatus, etc., is 32 tons 18lbs., the weight of the shield itself being 18 tons, but shields of much less weight can be constructed which will give a substantial resistance.

If the deflecting turn-tables, upon which the vertical V shields rest, were supported above the wooden deck on short drums or cylinders of sheet metal a foot or fifteen inches high, which would give an efficient support, while affording no material resistance to shot, being easily penetrable, but very difficult to cut entirely away, the danger of the shield being jammed fast by shot tearing up the wooden deck would be entirely obviated.

The vertical V shields were also recommended for the new ships by the Act of Congress providing for their construction, and they are also well adapted for land fortifications.

In considering the merits of these gun-shields, it should be remembered that the special appliances proposed will enable the guns of a ship to be operated with a much smaller crew; and, if the weight of the extra men required to work the guns by the present system, with all their belongings, and the provisions and water to sustain them, was credited to the shields, it would balance a large percentage of the weight entailed by them.

It will be seen that the armor of the proposed vessel is to be so arranged as to present no direct resistance to shot, but all the vital and offensive parts are covered by armor which protects deflectively, and the areas of the cross sections of armor are reduced to a minimum in order to present the least possible target to shot.

Projectiles are permitted to pass freely through the vessel, on the principle that the less resistance offered, the less injury received. Shot entering the side of the vessel would plow through the coal or stores packed in compartments above the curved shield, and would be deflected upward, that being the line of the least resistance, and would pass out through the far side of the vessel considerably above the water line.

As the men working the guns are all protected in appropriate deflecting shields, the upward flight of projectiles, after impinging on the curved shield, would not do any serious damage. Even though the

upper works of the ship were riddled, she would not be seriously damaged, as her vitals would remain intact.

As the crown of the curved shield rises above the water line, it thereby protects the vital far side of the vessel, where heavy shell would otherwise do the greatest damage by exploding against the frames at, and below, the water line and tearing off entire plates, thereby admitting such great volumes of water as to engulf a vessel at once.

The five vital factors of a war-ship are the water-line, the magazine, the motive power, the steering gear, and the personnel. In the proposed vessel, the first four of these and a part of the fifth are protected beneath the curved shield, the remainder of the personnel being protected in the deflecting gun-shields on the decks above.

In designing the machinery for a cruising war-ship it should be remembered that the requirements of such a vessel are entirely different from those of a passenger or fast freight steamer. The merchant steamer needs sustained high speed, with economy of fuel, to enable her to make her trips from port to port in the least possible time, and at the least expense, in order to pay a profit to her owners. The cruiser does not need sustained high speed, which can only be obtained with economy of fuel by great weight of machinery, but requires a still higher rate of speed, for short periods of time, in an emergency, when chasing an enemy or escaping from a superior force; and as this high rate of speed would be but seldom exercised, it is not admissible to carry a great weight of machinery in order to develope it with economy, and when exercised the cost of fuel would be a secondary consideration; on the other hand, it is absolutely necessary for the cruiser to be able to steam great distances, at a low rate of speed, with great economy of fuel, thereby enabling her to remain at sea for lengthened periods of time; but this low rate of speed cannot be economically developed by the machinery usually designed for sustained high speed.

According to the able and interesting report of Passed Assistant Engineer John A. Tobin, U. S. N., published as House Ex. Doc. 48, of the second Session of the Forty-seventh Congress, the average weight of the steam machinery of British merchant steamers is 480 pounds per indicated horse-power, and that of the light cruiser *Iris* is 289 pounds; and the average of the ships of the British navy is 360 pounds per horse-power, while that of the torpedo ram *Polyphemus* is 180 pounds, and of the two classes of swift torpedo boats the weight

of the steam machinery is only 57·7 and 66·5 pounds per indicated horse-power.

This remarkable reduction of weight is accomplished by the use of the locomotive tubular boiler, with air-tight fire-room and forced draught, furnishing steam of high pressure to very light machinery, constructed of steel and bronze, which transmits great power by its celerity of movement. The machinery is designed on what may be called the emergency principle.

Besides the *Polyphemus*, the cruisers recently constructed for the Chinese and Chilian governments have been engined partly on the emergency plan, the boiler being of the locomotive type, with air-tight fire rooms and forced draught, and have proved remarkably successful ships.

The steam machinery of the cruiser *Chicago* is to weigh 937 tons, and is to develope 5,000 indicated horses' power; this would give 419 pounds per horse-power. The steam machinery of the *Boston* and *Atlanta*, 3,000-ton cruisers, is to weigh 700 tons, and to develope 3,500 horses' power, which would give 448 pounds per horse-power.

If the 3,000-ton cruisers are taken as an illustration, it can be shown that the adoption of emergency power would permit of a reduction in the weight of machinery of 150 tons, which could be applied to give additional shield protection, and the attainment of an emergency speed of 18 knots per hour, with great economy of passage power; as when running at the lower rate of speed, a part of the engine power could be disconnected from the propelling instruments, thereby avoiding the loss from friction and radiation involved by an amount of machinery in excess of the power developed.

This feature would be an improvement on any vessel yet constructed and could be applied by gearing the crank shafts of vertical cylinder direct acting engines, to the shafts of twin screws, one compound engine being applied to the crank-shaft forward of, and the other aft of the driving pinion, with a disconnecting coupling on the crank-shaft for each, so that either, or both of the double cylinder compound engines could be used for driving the ship. A vessel of 3,000 tons displacement should have a central longitudinal bulkhead, dividing the under water body into two main comparments, which would be subdivided by athwartship bulkheads. Each screw would be driven by two separate, vertical-cylinder, direct-acting compound engines, the cylinders being placed close up against the central longitudinal bulk-

head in their respective compartments, in order to obtain the greatest available height under the crown of the curved shield, which would rise one foot above the water-line. Then if the crank-shafts were placed as low down as possible, there would be ample room under such a curved shield in the 3,000 ton ships for vertical-cylinder, direct acting engines of 36 inches stroke of piston, with connecting rods of 7 feet 3 inches in length.

Such engines geared down so as to make about two revolutions for each turn of the screw, designed to combine lightness with strength, like those of the torpedo boats, furnished with steam of high pressure, generated in locomotive tubular boilers, with air-tight fire-rooms, and forced draught, and having a piston speed of about 1,000 feet per minute—making about 165 revolutions per minute—thereby transmitting great power by very light machinery, by its rapidity of movement could easily develop the emergency power required within the limits of weight proposed, with great economy of passage power.

When running at a low rate of speed only one compound engine would be used to drive each screw, one engine being disconnected, thereby avoiding the loss from friction and radiation incident to running a greater amount of machinery, than is due to the power developed. When running at emergency speed, of course all the engines would be used to drive the ship. Such a form of machinery, would also be a great safeguard against accidents, as well as a source of economy when running at low speed, as the ship could be run, should occasion require, by any one of the four compound engines, and could not be totally disabled until all four engines, or their connections were broken down.

A thousand feet per minute may seem a very high piston speed, but some of the new torpedo boats having engines of 16 inches stroke of piston, make 480 turns of engine and screw per minute—there being no gearing—which is a piston speed of 1,280 feet. It should be remembered that the high emergency power would be but rarely called into action, and then for only a few hours at a time; it should, therefore, be classed with the battery as a weapon of war, never to be used except in an emergency.

It may be objected that with such extreme high power the coal supply would not last for more than four days continuous steaming; and, in reply it may be stated that the ordinary complement of ammunition would be exhausted by less than two hours rapid and continuous

firing. Under ordinary circumstances in time of peace the high emergency power would never be exerted, except for exercise or drill, in order to give the officers and men skill in its use when occasion required.

As the power necessary to drive a ship varies as the cube of her speed, and as it is estimated 3,500 horses' power will give the 3,000-ton ship a speed of 15 knots, therefore as $15^3 : 18^3 = 3,500 : 6,045$ horses' power, which with 550 tons of machinery would give 203 pounds per horse-power.

I am well aware it may be objected, the rule of the cubes might not hold good for so high a speed as 18 knots, but the margin between 57·7 and 203 pounds in the weight of machinery would far more than cover any discrepancy which could arise from that or any other cause. The British ship *Iris* having a displacement of 3,735 tons, made 18·587 knots per hour on the measured mile, with an indicated horse-power of 7,556; and the sister ship *Mercury* made 18·87 with a development of 7,514 horse-power. See "War-Ships and Navies of the World," by Chief Engineer J. W. King, U. S. Navy.

The 150 tons additional shield protection would permit of an excellent defense of the water-line, and admit of all the guns being mounted in the single gun turrets, or deflecting V shields, giving a substantial protection against the fire of heavy guns. According to the present designs, the guns' crews of the three new ships would be almost entirely exposed, as the guns are to be mounted in vertical cylindrical half turrets of only *two inches thickness of plating, presenting a direct resistance, three feet high, and open at the top,* with a light mantlet over the breech end of the gun, as a protection against light machine gun fire; such a disposition of armor is simply futile; a gun exposed in that way cannot be fought, and a gun that cannot be worked had better be left on shore. The same weight properly disposed would give both the water-line and guns' crews a fair measure of protection against the fire of heavy guns, but with the present disposition, it will simply encumber a ship with the weight of armor without giving her the benefit of its protection.

The vessels of 3,000 tons displacement now building—although provided with airtight fire rooms and forced draught—owing to badly disposed armor, ponderous machinery, and single screws, will not be equal in power of battery, speed, handiness, or sea endurance to the vessels of only 1,350 tons displacement constructed by Sir William Armstrong & Co. for the Chinese government; as those vessels each

carry two 26-ton ten-inch calibre guns, mounted on central pivots, one forward, and one aft, commanding a nearly all round fire. The charge of these guns is 180 pounds of powder, weight of projectile 400 pounds, and will penetrate 18 inches of solid iron armor. They carry in each, besides four 40-pounders, two 9-pounders, two Nordenfelts, and four Gatlings; and furthermore, they each carry two steam cutters fitted with spar torpedoes, and are fitted with knife rams, which their remarkable manœuvring qualities renders a formidable weapon. Such a battery is far superior to that proposed for the 3,000 ton cruisers consisting of two 8-inch guns, six 6-inch guns, and six machine guns.

The weight of the broadside of the Chinese cruiser of 1,350 tons, omitting the machine guns, is 988 pounds; while the weight of that proposed for the 3,000 ton cruisers would be 800 pounds, with far greater armor-penetrating power for the battery of the 1,350 ton ship.

At the trial trips of these Chinese vessels, "with all weights aboard one attained a speed of over 16 knots per hour, and the other 16 knots, while they developed remarkable manœuvering power. After going ahead at full speed, when the engines were stopped, the ship was brought to a stop in $3\frac{1}{2}$ lengths. With the engines reversed they were stopped in about $1\frac{1}{2}$ lengths. And with one engine going ahead and the other astern, they circled rapidly within their own length."

It is almost needless to say that no such handiness could be obtained from a vessel propelled by a single screw; nor anything like the speed from the 3,000 ton ships. (For description of Chinese cruisers see "The British Navy," by Sir Thomas Brassey, K. C. B., vol. 1, page 547.) The horse-power of these Chinese cruisers is 2,600, or 1·92 horses' power per ton of displacement; while the proposed 3,000 ton cruisers are to have 3,500 horses power, or 1·16 per ton of displacement. These vessels of 1,350 displacement carry 300 tons of coal, which will enable them to steam continuously for 28 days at 8 knots per hour; while the proposed 3,000 ton cruiser will carry 500 tons of coal, which will enable her to steam 27 days at the same rate. It will therefore be seen that the Chinese cruisers of 1,350 tons displacement, are superior to the proposed 3,000 ton ships in all the points enumerated, and it can also be shown that these smaller vessels, besides being more efficient, would cost far less for construction, and after maintenance.

Although the Chinese cruisers are superior to the proposed 3,000 ton ships, they are defective in having the crowns of their curved

shields, for the defense of the water line, placed so low, as to give no margin of buoyancy in the absence of water excluding stores when the sides of the vessel are penetrated, admitting water into the vessel above the shield, thereby sinking her. It may be urged that as the stores are used the ship would be lightened, and the crown raised, so as to exclude water; this is true, but as the crown is raised, so likewise are the submerged edges, and as such a lightened vessel rolled, she would expose her sides to penetration by projectiles below the shield. It will therefore be seen that the only alternative is to give the vessel by means of the shield a margin of buoyancy above the water-line, and to trim for action by admitting water to the cellular bottom; which will also give stability of gun platform to the ship.

These Chinese vessels also have all their guns mounted on the open deck—except, perhaps, light mantlets over the breech ends of the guns, as a protection against light machine gun fire—now, no matter what the size of a gun, it is not of any use, unless it can be worked, and no gun can be worked on the open deck, if opposed by a battery of Hotchkiss revolving cannon mounted in the light vertical V shields of only two tons weight, of the type described and illustrated in this article. If half the weight of the guns was put into such shields, it would be a great improvement.

The Chinese cruisers are also defective in being fitted with horizontal engines, as such a form of steam machinery occasions greater loss from friction, wears out more rapidly, and is more difficult to keep in repair than the vertical type. The vertical cylinder engine is the only form that should ever be put into a screw ship.

If the plans of the 3,000 ton cruisers *Boston* and *Atlanta* were modified in accordance with the designs herein advocated, including adequate water-line, and gun-shield protection, with emergency power engines, they would produce vessels not only superior to the Chinese cruisers, but ships having sufficient defensive and offensive powers as to enable them to successfully contend with armor clads of much greater displacement, combined with higher emergency speed, and greater sea endurance, which would give them great value as commerce destroyers.

If it is considered more desirable to retain the same speed, and construct vessels of greater defensive and offensive powers by giving the 3,000 ton cruisers only 3,500 horse-power as is now proposed, the weight of such steam machinery on the emergency plan basis of 203 pounds per indicated horse-power, would be 321 tons, 1,460 pounds,

leaving 378 tons, 780 pounds of the 700 tons now allowed for steam machinery, for increasing the defensive and offensive powers of the ship.

This 378 tons saved from steam machinery by the adoption of the emergency principle, if put into heavy guns and deflective armor judiciously disposed, would produce a vessel which could contend successfully with any armor clad now in existence. Or this weight could be distributed to increase the defensive, offensive, and motive powers.

If the 3,000 ton ships were supplied with petroleum for fuel in time of war, it would increase their sea endurance threefold, and enable them to steam continuously at 7 knots per hour, for 120 days, during which time they could traverse 19,160 nautical miles. This great sea endurance, with the great factor of safety in their steam machinery, by its division into four separate compound engines, any one of which could be used for driving the ship, should the others be disabled, would make the vessel entirely independent of sail power.

Besides the three vessels before mentioned, provided with shield protection, the Naval Advisory Board has designed a fourth, of 1,500 tons displacement, having no shield protection, in which defensive and offensive power are intentionally sacrificed to lightness and and speed. This vessel, to be called the *Dolphin*, is to be armed with a single 6-inch gun, mounted on the open deck, and four machine guns mounted in direct resistance shields. The boilers will be partly above the water-line, and the engines will project 11 feet 6 inches above it. This ship is intended for an armed dispatch vessel. The British Government has recently constructed two vessels, the *Iris* and the *Mercury*, for similar service, but the steam machinery of those vessels is protected by being entirely below the water-line.

The *Dolphin* is now building, and the Naval Advisory Board, in a letter addressed to the Honorable Secretary of the Navy, dated October 25, 1883, has recommended that another similar vessel be constructed next year; claiming that such vessels would be very useful for the performance of the multifarious duties of general cruising, survey, and exploration, etc., in time of peace, and as commerce destroyers in time of war.

There is no question but that the *Dolphin* would make a very successful *war-vessel in time of peace*, and, if we were building a *peace navy*, her type would do very well; but if, while serving as a commerce destroyer in time of war, she should unfortunately meet an

armed vessel of the enemy of less size, similar to the Chinese cruisers, she would simply have to haul down her flag, for she would not have the power of battery to fight, nor the speed to run away.

In event of war, any desirable number of commerce destroyers, equally as efficient as the *Dolphin*, could easily be improvised, by making slight modifications to our coastwise steamers, while fighting ships cannot be improvised, but require to be laboriously constructed for that special purpose, involving a considerable period of time. Therefore it is certainly poor policy to expend any part of the small appropriatons obtainable for the increase of the Navy, while it is in its present weak condition, for any other purpose than the construction of fighting ships.

Instead of first designing a combination of hull and shield which would give the greatest measure of protection to the greatest interior space, with the least weight of armor, and then placing a suitable form of engines within that space, the board seem to have first determined upon the type and dimensions of the engines, and then to have built the ships around them.

The machinery of all four ships is either exposed above, or so disposed below the water-line as to vitiate any benefit to be obtained from shield protection. In the twin screw cruiser *Chicago* the ends of the beams of the anomalous engines project so far toward the sides as only to be covered by a shield presenting an angle of 27° to horizontal fire, which with 1½ inches of plating is a mere travesty on protection. In the *Boston* and *Atlanta*, the engines, being horizontal, do not interfere, but the boilers project out so far as to require a shield of 28°, which with 1½ inches thickness of plating is simply futile; and in the *Dolphin*, a war-ship designed *for service "in time of peace,"* the engines themselves project 11 feet 6 inches above the water-line.

It will be understood by every practical mechanic, or other person of ordinary intelligence and common-sense, that there is no need whatever for this exposure of the machinery above, or improper disposition of it below the water-line; for the small vertical cylinder rapid-moving engines herein described, which are analogous to those which produce such marvelous speed for the torpedo boats, geared down to the revolutions of the screw, can be worked and completely protected under the crown of a curved shield of a vessel of only 6 feet draught, with the crown of the shield rising 1 foot above the water-line. Of course a vessel of such very light draught would not have a double

bottom, but when a double bottom is used there would be no objections to recessing the small driving pinion, and cranks into it, in order to increase the height for the small vertical direct acting engines.

In this connection it may be well to state that to gear a screw up, in order to make it turn faster than the engine, requires very heavy machinery, while to gear it down, as proposed, may be accomplished by very light machinery.

The locomotive type of boiler will also go under the curved shields of the lightest draught vessels.

It may be objected that the locomotive boiler is not one of great endurance, that it is not the form best suited for use on shipboard. To this it may be answered, as the power necessary to drive a ship 18 knots is 8 times as great as that needed to drive her 9 knots, which speed would not be exceeded except on rare occasions, therefore sufficient boiler power of the ordinary type could easily be carried to develope the passage power, with a very slight increase in weight, while the emergency power would be obtained from steam generated in the much lighter locomotive type.

If geared engines should be objected to there is room under the curved shield of the 3,000 ton ship for vertical-cylinder, direct-acting engines of short stroke; or for what would probably be still better, vertical-cylinder engines, set up close against the central longitudinal bulk-head, in order to obtain the greatest vertical height, with vibrating bell-crank levers; by such a type of engines a length of stroke of five feet could be obtained.

As the steam machinery of the first class torpedo boats weighs but 57·7 pounds per indicated horse-power, the difference between that weight and 419 pounds in the *Chicago*, and 448 pounds in the *Boston* and *Atlanta*, seems to be a high price to pay for the *economy* of fuel to be obtained by its use on rare occasions, for short periods of time, particularly when we consider this ponderous machinery itself has to be carried at the high speed, and that additional power has to be applied to overcome the resistance due to the displacement incident to its weight.

Besides, it should be remembered, this heavy machinery, if properly proportioned for sustained high speed, could not be run with economy at the low rate of speed at which a war-vessel consumes by far the greater part of her coal. The new ships are designed to effect economy in the consumption of one-twentieth part of the fuel—that used

at high speed—and for wasteful extravagance in the consumption of the remaining nineteen-twentieths; and are handicapped with an enormous weight to produce this result. It will therefore be seen that true economy is obtained by the use of the light rapid-working engines, which type has of late years been found to give the greatest measure of economy on shore, where the problem is not complicated by displacement, resistance and space.

I do not propose to construct steam machinery for cruising vessels on a basis of 57·7 pounds per indicated horse-power, but to take 550 tons of the 700 allowed for the machinery of 3,000-ton cruisers *Boston* and *Atlanta*, and with it to give them sufficient power to drive them 18 knots per hour; and if it required 6,045 horse-power to attain that speed, it would allow 203 pounds per horse-power. The 150 tons saved from machinery would permit of an adequate defence for the water-line, heavier guns, and when mounted in the single-gun turrets, or V shields, of a very large measure of protection for the few men necessary to work these guns, even against the fire of guns of equal power.

In reply to some severe criticisms by the London *Engineer* on the Naval Advisory Board, and the ships it has designed, the secretary of the board replies that the same statements "condemn five of the most approved new British cruisers, which are substantially of the same description as to protection, weight of battery, thickness of deck," etc. This assertion is not correct; but admitting, for the sake of argument, that it was strictly so, would that be sufficient excuse for the board to inflict similarly worthless vessels upon the American navy? If the board had authority to construct a ram is it to be understood they would copy the British *Polyphemus?*

The Admiralty modified the excellent plan of deflective ram, designed by Rear-Admiral Ammen, U. S. N., until, by various improvements—one of which was the securing of three hundred tons of cast iron on her bottom, to be dropped into the sea to ensure her buoyancy if she should spring a leak—they produced the *Polyphemus*, a complete failure; and they seem to have improved the curved deflective shield, until they produced that of the *Leander*,—this, however, has been termed "the development of armor"—and now the board, by a further improvement in the same direction, by adding six or eight degrees to the horizontal angle of incidence, have produced the shield of the *Boston* and *Atlanta*.

Our navy, at the present time, is in a truly deplorable condition, consisting as it does almost entirely of obsolete wooden ships, and still more obsolete guns. With the present range of improved rifled guns, the projectiles of some of which weigh as much as a ton, the four important cities of New York, Boston, Portsmouth and Norfolk could be shelled from the open sea, by armor clads laying in twenty-four feet of water. These four cities are designated because they each have a national navy yard in close proximity to their centres of population, and it would be the duty of the admiral commanding any hostile fleet sent against us, to destroy these naval stations, and from the unsteady platform of a vessel at sea it would be impossile to prevent shell from dropping around a radius of several miles from the point aimed at. This would, no doubt, be the excuse for laying the wealthy cities of New York and Boston under heavy contribution. Aside from the direct loss, the indirect loss from panic, depreciation in values, and disturbance of business would be enormous, far more than enough to build twenty small navies such as we require. And it must not be supposed the entire loss would fall upon the seaboard ; if the exit through the port of New York or San Francisco was stopped by a single foreign armor clad for only twenty-four hours, what effect would it have on the values of the western products, corn, wheat flour, and pork, and of the cotton of the south? Twenty-four hours blockade would occasion a financial revulsion, inflicting a greater loss on the business community than the cost of twenty navies. It would touch the pocket nerve of every producer in the country.

At the present time our entire coast, including some of its chief cities, of enormous wealth, is entirely at the mercy of any third rate naval power which happens to possess two or three modern armored vessels. The present condition of our navy simply invites attack.

It has been asserted that we could defend our coast with torpedoes, but those who are competent to judge of such a matter knows that torpedoes are only an adjunct, very useful, in fact indispensable, but that the unit of force is the gun-bearing vessel, from under whose fire torpedoes can be most effectively used, and by which an enemy can be pursued, destroyed, or captured ; and the scene of combat removed from our own firesides.

The plan contemplates quite an inexpensive navy, which should commend it to economists, it is based on the simple laws and practices of mechanics, with nothing abstruse or complicated about it, and

should therefore be supported by people of common sense; and it proposes to construct ships and not coffins, a feature which should commend it to the favor of every professional seafaring man.

Some of the foreign armored vessels now building cost from four to five million dollars each, while no vessel built upon this plan need cost more than one million, and the great majority not more than half that sum; and very efficient ships can be produced, fully armed and equipped at a cost of $300,000.

When it is considered that any vessel, no matter what her size, can be completely wrecked by a well directed torpedo, and that the larger the vessel the greater the danger of such a calamity, the folly of building such unwieldy ships, and the wisdom of constructing the smaller and cheaper ones, on the plan herein proposed, will be appreciated.

Every State, county, city, township, and borough in the land, maintains officers, at great expense, to protect persons and property, and enforce the laws against evil doers; and as there is probably almost as much moral depravity in the conduct of nations as there is in that of individuals, it is absolutely necessary to maintain an armed force, for the protection of property on, and adjacent to the sea.

Last year Congress appropriated $1,300,000 for the reconstruction of the navy, assuming that the country contains 54,000,000 people, this would be but $2\frac{4}{10}$ cents each; surely not an extravagant expenditure.

It has been asserted that, in event of war, our adversaries, whoever they might be could purchase some of the swift transatlantic steamers, and with them destroy our coastwise commerce, which is perfectly true, but such improvised war ships, even if armed with heavy guns, would not dare attack a regularly constructed war ship, if designed upon the plan herein advocated, for it would be feasable to construct such a vessel, even upon so small a displacement as 1,000 or 1,500 tons, with an emergency speed by which they could be run down, and then by firing single the forward pivot gun into the stern on a line with the keel, the engines projecting far above the water line would be disabled; or, if that should fail, such a ship could be easily be disabled by running the projecting ram of the pursuing vessel into the track of the propeller, which would be stripped of its blades by its own revolving power, then circling around the disabled vessel to a position abeam, a threat to ram would bring down her flag.

Owing to their defenceless water-lines it would be impossible to keep any one of the four new ships afloat in action under the fire of modern

guns; and as there is not a gun on any one of them which could be fired in action, if opposed by a battery of machine guns of $1\frac{1}{2}$ inches calibre, mounted in V shields of two tons weight each, it is quite feasible to construct a vessel of the same speed and displacement as the *Dolphin*, engined on the emergency plan, and armed with two 10-inch pivot rifles, and a battery of $1\frac{1}{2}$ inch machine guns mounted in V shields, which would be more than a match for all four of the new ships combined.

ELECTRO-PLATING WITH NICKEL.

By William H. Wahl.

[A paper read before the Chemical Section of the Franklin Institute, Nov. 6, 1883.]

Nickel-plating is an American industry, in the sense that it was first successfully practised on the commercial scale in the United States, and here received that practical demonstration of its usefulness that has since made it the most successful and most widely practised branch of the art of electro-plating. Coming first into prominence and popularity about ten years ago, it has since that time rapidly grown, until to-day it has developed into an industry of great magnitude. The almost silvery whiteness and admirable brilliancy of electro-deposited nickel; its cheapness as compared with silver; the hardness of the electro-deposited metal, which gives the coating great power to resist wear and abrasion; the fact that it is not blackened by the action of sulphurous vapors which rapidly tarnish silver; and the circumstance that it exhibits but little tendency to oxidize even in the presence of moisture, are sufficient to explain the great popularity which nickel-plating enjoys.

The industrial development of the art, however, which has been surprising both in respect to its rapidity and extent, may be attributed in a large measure, to certain favoring circumstances, quite independent of the excellent adaptability of the metal for electro-plating purposes. These circumstances are: first, the great advances that have been made within the period above named, in the production of nickel on the commercial scale, by which the cost of the metal has been greatly reduced, and its purity greatly increased, for which we are indebted largely to the American Nickel Works of Camden, N. J.,

Fig. 9.

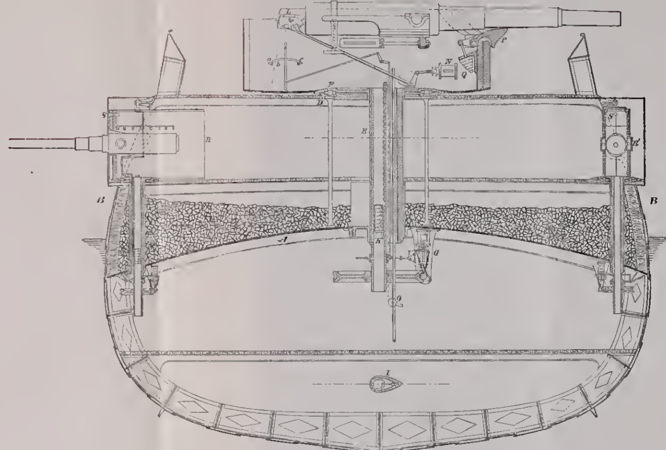


Fig. 12.

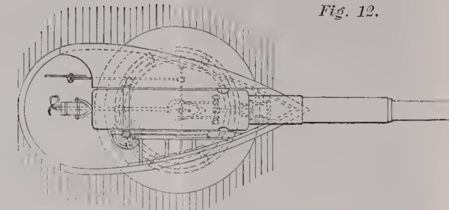


Fig. 11

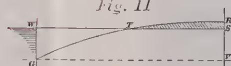


Fig. 10

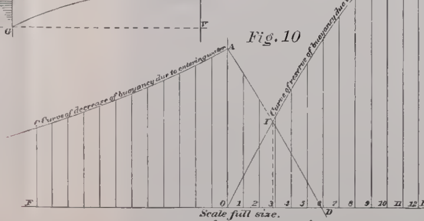


Fig. 13.

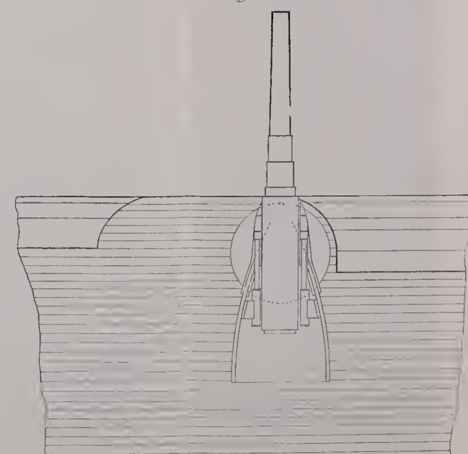


Fig. 12.

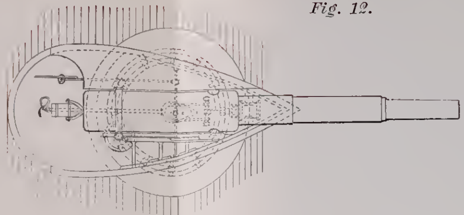


Fig. 13.

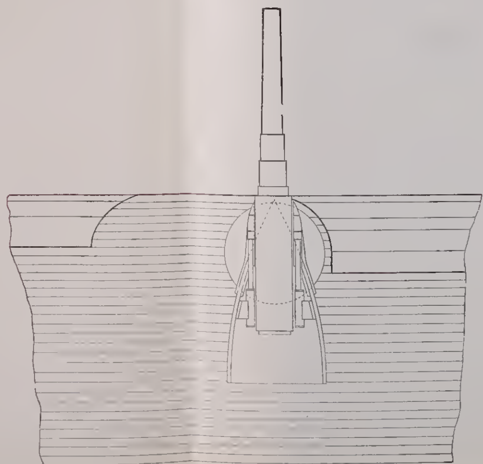


Fig. 14.

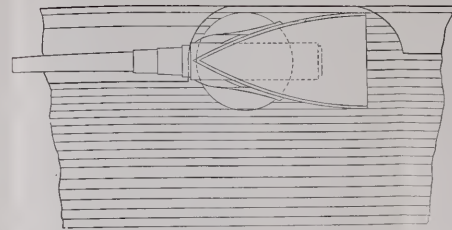


Fig. 15.

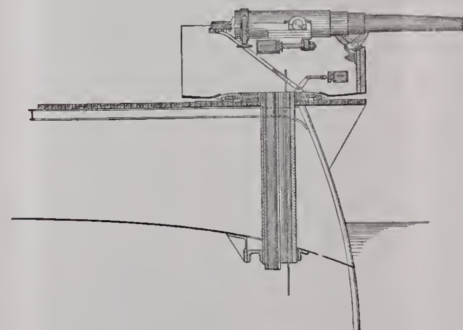
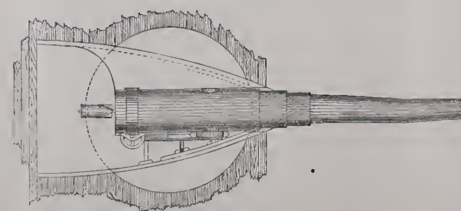


Fig. 16.



Plan of the Huascar (Showing hits by Shot)

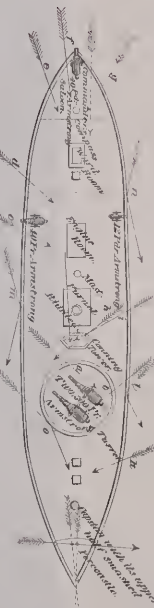


Fig. 41.

under the scientific management of Mr. Joseph Wharton:* and second, the introduction and great improvement within this period, of the dynamo-electric machine, which placed at the disposal of electro-

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* Mr. Wharton has produced at his works in Camden, N. J., since the year 1876, to the close of the year 1882, 1,466,765 pounds of metallic nickel. He began experimenting very early to determine whether nickel could not be produced in a pure and malleable condition, susceptible of being worked in nearly the same manner as iron, and of being applied in the manufacture of various objects demanding a strong, non-oxidizable metal. He succeeded so well that he was enabled to display at the International Exhibition in Vienna, in 1873, a sample of nickel in the form of axles and axle-bearings; and at the Philadelphia Exhibiton, three years later, he exhibited a remarkable series of objects made of *wrought nickel*, such as bars, rods, etc. These objects from their unpretentious character did not attract the attention they deserved. As a matter of justice to this indefatigable and intelligent worker, the fact should be placed on permanent record that he had succeeded as early as the year 1873, and with the lean and sulphuretted ores of Lancaster Gap, Pennsylvania, which yield only from 1½ to 2 per cent. of nickel, in producing the metal in malleable condition.

The recent discovery of pure carbonated and oxidized ores of nickel in the French colony of New Caledonia, has greatly stimulated the production of this metal and lessened its price; and the highly ingenious refining process recently discovered by Dr Fleitmann, which is now altogether used in the production of the pure metal, has tended in the same direction.

The subject is of such interest that I quote the following brief account of Fleitmann's process, from a paper read before the American Institute of Mining Engineers at their meeting in Boston, in 1882, by Prof, W. P. Blake, of New Haven, viz:

"Dr. Fleitmann, of Iserlohn, Westphalia, Prussia, has improved and cheapened the operation of refining nickel and toughening it, and has reduced the liability to the presence of blow-holes in castings by adding to the molten charge, in the pot, when ready to pour, a very small quantity of magnesium. This is immediately decomposed, magnesia is formed, and graphite is separated. It would seem that the magnesium decomposes the occluded carbonic oxide, or reduces it to a minimum. The magnesium must be added with great care, and in small portions, as it unites explosively with the charge. It is stirred in. About one ounce of magnesium is sufficient for 60 pounds of nickel. From three-quarters of an ounce to 34 pounds of metal have been used with success by Mr. Wharton. The nickel from the ore at Lancaster Gap seems not to require as much as the foreign metal. It is to be noted that complete malleability of nickel was obtained at Wharton's works in Camden, before Fleitmann's invention or process, but this last is more rapid and better than the old method. The metal so treated becomes remarkably tough and malleable, and may be rolled into sheets and draw into wire. Cast plates can be successfully rolled. The cast plates,

platers a constant, powerful, and cheap source of electricity, in the place of the uncertain, troublesome, and comparatively expensive voltaic battery, to the use of which they had of necessity been hitherto confined. Alex. Watt * was among the first, I believe, to call attention to these facts. He states for example that "the difficulty in obtaining pure nickel anodes of large surface, for many years checked the progress of this useful art, whilst the slow and uncertain action of the ordinary battery rendered it ill-suited to the deposition of this peculiar metal on the large scale;" again, "it is doubtful whether nickel-plating would ever have held a really high position in the arts, if the dynamo-electic machine had not been introduced;" and in another place: "Indeed, as we have said, it is doubtful if this branch of the art (*i. e.* nickel-plating) could even have been extenisvely pursued with advantage on a large scale, if battery power alone were available." In considering the subject of the present very extensive application of nickel-plating, therefore, the above facts and explanations should not be lost sight of. So general has the demand for nickel-plating grown to be, and so universally is it employed, that, for the sake of economy,

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such as are made for anodes, after reheating; are rolled down to the desired thickness. It is found that it is a great improvement to the nickel anode plates to roll them down. They dissolve with greater uniformity in the bath. Nickel so treated with magnesium has been rolled into sheets as thin as paper. Expensive works for rolling the metal have been erected by Mr. Wharton at Camden. There is already a train of 40-inch rolls, 18 inches in diameter, with annealing-ovens and gas-furnaces and their adjuncts, and a 90 horse-power engine. The largest sheet yet rolled at Camden is 72 inches long and 24 inches wide, of pure nickel.

"Dr. Fleitmann has also succeeded in welding sheet-nickel upon iron and steel plates, so as to coat them equally on each face with a layer of nickel. The quantity preferred by weight is $\frac{8}{10}$ iron and $\frac{2}{10}$ nickel, one-tenth of nickel being placed on each surface. To secure union, the iron or steel must be perfectly flat and clean. A pile is made with outer facings of sheet-iron, to protect the nickel from scaling. When the whole is heated to the proper degree, it is passed through the rolls. The two metals become so firmly united that they may afterward be rolled down two or three together, or separately, to the thinness desired."

Consult also, *Jour. Franklin Institute.* cxvi, 60, *et seq.*, Art. Notes on the Metallurgy of Nickel in the United States. By Wm. P. Blake, F.G.S.

Also *Galvanoplastic Manipulations.* By William H. Wahl, Ph.D., Philadelphia. H. C. Baird & Co., 1883.

* "*Electro-Metallurgy*, Practically Treated." By Alexander Watt, F.R.S.S.A. 7th Ed., 1880. p. 86, *et seq.*

hundreds of establishments throughout the United States engaged in the manufacture of the most miscellaneous articles of brass, copper, iron and steel have introduced the nickel-plating plant, and do their own plating. Furthermore, innumerable small articles of metal of trifling value are nickel-plated after a fashion, by the manufacturers, not to protect them from the action of corrosive agents, but simply to catch the eye of the purchaser and to make them sell. As may readily be imagined, this state of things has produced a severe competition among those engaged in the business of nickel-plating which, while it has had the effect of bringing down prices to extremly low figures, has incidentally also had the effect of causing a very general deterioration of its quality.

An enumeration of the great variety of products that are nickel-plated would be impossible; among them may be named dental and surgical instruments of every description, harness- and saddlery-trimmings, carriage-fittings, spoons and forks, locksmith's work, brass cocks and faucets, and the decorative metal-work of plumbing and sanitary wares, scale- and balance-beams and weights, mountings of guns and pistols, the metal parts of lamps and lanterns, fire grates and fixtures, stove decorations, door-plates, cuspadores, watch- and clock-cases, hand-rails of railway cars and car-seats, etc., stair rods, points of lightning rods, show-cases, the external parts of sewing machines, steam and water valves, gauges, and miscellaneous machinery accessories without number.

From the very brief account that M. Roseleur gives of this subject, it would appear that the art of nickel-plating had received little or no attention in France up to the year 1880;* furthermore from the somewhat contemptuous reference with which he dismisses it, it is apparent that at that time he had no knowledge of the remarkable progress and development of the art in this country, and no conception either of the perfection to which the processes had been brought, or the beauty and utility of the results obtained.

Although, however, it would appear from the remarks of the author, just referred to, that nickel-plating had received but little attention in France up to the year 1880, the art appears to have been transplanted to England with much success, as the following reference to the subject

* *Manipulations Hydroplastiques*, etc.; *par* Alfred Roseleur. 4e. Ed. Paris, 1880, p. 300.

by Watt* will testify: "the time has now arrived, however, when it may be fairly stated that the art of nickel-plating has become, in proper hands, one of the most successful, and at the same time one of the most extensive branches of electro-deposition. For several years nickel-plating in this country (*i. e.* England) had been principally confined to some three or four houses. Now, however (1880), the process has been most extensively adopted in London and throughout the kingdom, as also in many foreign countries. There is no doubt that its extensive application in the United States acted as a stimulus to our own manufacturers, who have steadily, though tardily, recognized in nickel a most useful coating for certain kinds of metal work."

NICKEL SOLUTIONS.

One of the earliest allusions to the electro-deposition of nickel is that of M. Ruoltz† in the year 1841. The reference is as follows: "The same method, that is, the use of a solution of the double cyanide in water (prepared by dissolving the metallic oxides in cyanide of potassium), may be employed for coating other metals with copper, tin, cobalt, *nickel*, and zinc." In 1843 Smee‡ states that "metals may be covered with nickel by proceeding as in former cases. The solution to be used is the chloride of nickel with a nickel positive pole. The single battery process is to be preferred, but pure nickel, though *very brilliant*, is apt to be rather brittle. . . . It is best reduced by the compound battery process, with a platinum positive pole, though a nickel positive pole may be employed. When we employ either the nitrate or sulphate of nickel for electro-metallurgy, it is preferable to use the solution as strong as possible. Of the compounds of these salts with the alkalies, those with ammonia deserve the preference, and the ammonio-nitrate and the ammonio-sulphate may be used for the reduction of this rather troublesome metal." In the same year (1843), Dr. R. Bœttger§ published an interesting account of his experiments in plating with nickel from which I take the following quotations: "No salt of nickel or of platinum has yet been found well adapted to plating baser metals with nickel or platinum. Experience has taught that a

* *Electro-Metallurgy*, p. 87, *et seq.*

† Ruoltz, *L'Institut*, Nr. 414, p. 410; also Berzelius *Jahresber.* xxii, p. 96.

‡ Smee, *Elements of Electro-Metallurgy*, 2d (Lond.) Ed, 1843. pp. 154, 219.

§ *Jour. f. prakt. Chem.*, xxx, p. 267, *et. seq.*

compound of cyanide of nickel with cyanide of potassium, according to the statement of Ruoltz, by no means attains the object, nor is the platinum salt recommended by him any better."

"From a long series of experiments expressly made on this point, I believe I have discovered, and can give the assurance that among all the salts of nickel none is so well adapted to plating, especially on copper or brass, as the ammonio-sulphate of nickel; at least, the cyanide of nickel and potassium recommended by Ruoltz is far inferior to it, even in a very long-continued, constant current. Sheet copper comes out of the solution of ammonio-sulphate of nickel almost *silver white* and *brilliant*. I have obtained in this manner, after the action of a moderately strong galvanic current for half an hour, a considerable deposit of nickel on copper, quite sufficient to deflect violently from the magnetic meredian, a magnetic needle suspended by a fibre of silk. A drop of common nitric acid on the nickel coating exhibited in a given time no sensible action on the subjacent metal, while sheet copper which had been allowed to remain in a gilding bath under the influence of the current for the same length of time, was almost instantly attacked by nitric acid. From this it may be inferred that the galvanically deposited nickel coats the copper more rapidly, adherently, and uniformly than gold similarly deposited." . . . . . .

"To prepare the salt of nickel here referred to, the impure nickel of commerce suffices completely. To this end, it is dissolved in nitric acid, a stream of sulphuretted-hydrogen is passed through the solution for some time in order to precipitate all copper and arsenic, and the filtered solution is then precipitated by carbonate of soda. The well-washed carbonate of nickel is dissolved in dilute sulphuric acid, and the solution is placed beneath a bell-glass over concentrated sulphuric acid, in order to obtain it crystallized. These crystals are pulverized, transferred to a suitable flask, and ammonia gradually poured over them, until sufficient has been added to dissolve them. The resulting fine, dark-blue solution, may be directly used for the purposes above named."

It may be proper to add, in this connection, that one of the uses suggested by Bœttger for his solution is for the preparation of pure sheet nickel.

In the fourth edition of his work Roseleur* affirms that as early as

* *Manipulations Hydroplastiques*, etc.; *par* Alfred Roseleur. Paris, 1880, p. 301.

the year 1849 he had succeeded in the establishment of M. Kraintz, at Grenelle, in obtaining on table-ware an excellent deposit of nickel of considerable thickness, with the use of the double sulphite of nickel and ammonium as the depositing solution.

The next important contribution to the art of depositing nickel by galvanic means is made by Mr. George Gore, who, in 1855, employed the double salts of nickel and ammonium, *i. e.*, the double chloride. In the edition of his work on *Electro-Metallurgy*, published in 1860 (Griffin & Co., London, 1860), he describes a method for the electro-deposition of nickel by means of a solution of the double chloride of nickel and ammonium.

In 1862, MM. Becquerel, *père et fils*, read before the French Academy a paper on the "Electro-Chemical Reduction of Nickel, etc.,"* from which I quote as follows: "Nickel, we operate with a solution of sulphate of nickel to which has been added caustic potassa, soda, or ammonia, preferably the latter alkali, to saturate the excess of acid. Sulphuric acid becoming free is saturated by oxide of nickel placed on the bottom of the vessel, or by adding alkali to the solution, ammonia by preference. At the end of a certain time we obtain a brilliant, white deposit with a slightly yellow tint. According to the moulds employed it may be obtained in cylinders, bars, or medals. They possess, like cobalt, magnetic polarity when taken out of the solution. The ammoniacal solution of the double sulphate of nickel and ammonium, and even that which is not ammoniacal, likewise furnish metallic nickel."

In 1869, Isaac Adams, Jr.,† of Boston, obtained a patent in the United States for an "Improvement in the Electro-Deposition of Nickel," in which he describes a method of preparing the double salts of nickel—the double sulphate of nickel and ammonium, and the double chloride of nickel and ammonium—by which the same are obtained free from certain impurities, to the presence of which, he claimed, the difficulties in the way of obtaining a satisfactory deposit of this metal by galvanic means were ascribable. He describes in his patent specification a method of preparing these two compounds in

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* *Reduction electrochimique du cobalt, du nickel, de l'or, de l'argent et du platine*; par MM. Becquerel et Ed. Becquerel. *Comptes Rendus*, lv, p. 19, *et seq.*

† Consult U. S. Pat., No. 93,157, August 3, 1869; or British Pat. No. 31,251, October 28, 1869.

such a manner as to be free from the presence of potash, soda, lime, alumina, and nitric acid, and directs that the electro-deposition of nickel by means of either of these double salts must be done from a solution that is free from acid or alkaline reaction. He likewise claims as his invention a method of preparing the nickel plates to be used as anodes in the depositing cells, which consists in melting the nickel and combining it with iron, for the purpose of avoiding the bad effects produced by copper and arsenic when these are present as impurities in commercial nickel. The effect of the addition of iron to the nickel (the amount being the chemical equivalent of the copper and arsenic present), Mr. Adams affirms, is to prevent the deposition of the above named impurities with the nickel. Quoting from the specification, "the iron itself is almost wholly precipitated as a peroxide, and is not deposited with the nickel to a sufficient extent to injure the character of the deposit. Neither does it injuriously affect the solution. The effect of the iron upon the copper is either to prevent it from being dissolved, or, if dissolved, to immediately reduce it upon the anode where it forms a coating which may be reduced from time to time by scraping. The arsenic forms an insoluble precipitate with the persalt of iron."

Mr. Adams continues:

"Having prepared the solutions and anodes, as herein described, nickel may be readily deposited; but, in order to carry on the deposition continuously, it is necessary to observe certain precautions: First, the use of a battery of too high an intensity must be avoided. An intensity of two Smee cells is sufficient. A high intensity decomposes the solution and liberates free ammonia, thus rendering the solution alkaline, and impairing its value. Whenever the smell of free ammonia arises from the decomposing cell the operator may be certain that the solution is being injured. It is important that the depositing shall not be forced by the use of too strong a current. Second, it is important that great precaution should be used to prevent the introduction into the solution of even minute quantities of potash, soda, or nitric acid. When an article to be coated is cleaned in acid or alkaline water, or is introduced into it for any purpose, the greatest care must be taken to remove all traces of these substances before the article is introduced to the nickel solution, as the introduction of the most minute quantities of acids or alkalies will surely be injurious. It is important that the solution be kept free from all foreign substances,

but its purity from those above named is especially important. Third, the anode of the depositing cell should present a surface to the action of the solution somewhat larger than the surface upon which the deposit is being made, particularly in the double sulphate solution. The reason is that nickel dissolves so slowly, that if the exposed surface is not larger than the surface on which the deposit is made, the solution will not keep saturated. On the other hand, if the anode is very much larger than the positive pole it tends to give a deposit of black powder. Fourth, if zinc is to be coated it should first be coated with copper, as it is difficult to make nickel adhere to zinc, and there is danger that the zinc may be acted on and injure the solution.

"With solutions and anodes thus prepared and used, the deposition of nickel can be carried on continuously and almost as surely and certainly as the deposition of copper from the common sulphate solution, though the limits of the battery-power which may be used are narrower. The metal deposited is compact, cohesive, and tenacious. It may be deposited of nearly uniform thickness over any surface, however, large. The deposited metal is capable of being annealed by a heat below a low-red heat. It then becomes flexible, malleable, and ductile. The deposit may be made of any required thickness, either to furnish effectual protection to the metal on which it is deposited, or to be removed and used separately from the surface on which it may be deposited."

In the same year, but a few months earlier than the date of the patent above referred to, a patent had been granted to the same inventor for the use of a solution of the sulphite of nickel in a solution of sulphite or bisulphite of ammonium.* This solution is identical, apparently, with that which M. Roseleur claims† to have used as early as 1849, with excellent results, in the establishment of M. Kraintz at Grenelle, but which, as I glean from a *Notice supplémentaire sur le Nickelage,* which he has lately issued, he has discarded in favor of the double sulphate.

The Adams patents were the first on the subject of nickel-plating in the United States, and the rapid development of the art to the proportions of an important industry, which took place within a few years thereafter, gives color to the claim that Mr. Adams is entitled to

* Consult U. S. Pat., No. 90,332, May 25, 1869.

† See *ante.*

the credit of being the originator of the art of nickel-plating. I have elsewhere pointed out that the true explanation of the remarkable growth of this art is to be found in the substantial improvements in the metallurgical treatment of nickel, by which anodes of any desired size, and of great purity, were placed at the service of the nickel-plater; and more especially in the invention and improvement of the dynamo-electric machine, which has made the nickel-plater independent of the uncertain and troublesome voltaic battery. Had it not been for the want of these two important elements of success in this branch of the galvanoplastic art, plating with nickel would unquestionably have been extensively practised, years before it actually assumed a position as a successful and popular industry.

It cannot be denied, however, that Mr. Adams, by directing the attention of technologists to the excellent qualities of the double salts of nickel and ammonium at a time when everything was ripe for the new industry, materially assisted in calling it into existence, and in assuring its commercial success.

The years immediately succeeding 1869 were very prolific of inventions relating to the art of nickel-plating, many of which, however, were comparatively valueless. I select for notice few that appear to have meritorious features.

In 1877, John Unwin* of Sheffield (England) devised an ingenious process of preparing the double salts of nickel and ammonium. This consists in preparing a strong solution of sulphate of ammonium, by dissolving the salt in hot water in the proportion of about 4 pounds of the salt to each gallon of water, then filtering if necessary, and allowing the liquid to become cool. The double sulphate of nickel and ammonium is obtained by adding this solution to one of the sulphate of nickel. The novelty of Mr. Unwin's process, however, resides in the fact that he does not stop the addition of the sulphate of ammonium when sufficient has been added to combine with all the sulphate of nickel present, but continues to add it in large excess. "I do this," says Mr. Unwin, "because I have discovered that the double sulphate of nickel and ammonia is far less soluble in the solution of sulphate of ammonia, than in pure water, so that it is precipitated from its solution in water on adding sulphate of ammonia. I therefore continue adding the solution of sulphate of ammonia, continuously stirring,

* Consult British Pat., No. 1,548, April 20, 1877.

until the liquid loses nearly all its color, by which time the double sulphate of nickel and ammonia will have been precipitated as a light-blue crystalline powder, which readily settles to the bottom of the vessel. I then pour off the liquid from the crystalline precipitate of double sulphate of nickel and ammonia and wash the latter quickly with a strong, cold solution of sulphate of ammonia as often as I consider necessary for its sufficient purification." By this procedure it will be perceived, the double salt of nickel and ammonium is thrown down in a pulverulent, granular condition, readily soluble in water, and therefore ready for use in the depositing vat, without waiting for the tedious process of crystallization.

In 1878, Edward Weston,* of Newark, N. J., noticing its favorable influence upon the electro-deposition of nickel, secured a patent for "the electro-deposition of nickel by means of a solution of the salts of nickel containing boric acid, either in its free or combined state. The nickel salts may be either single or double." Mr. Weston affirms that the presence of boric acid prevents the deposit of sub-salts upon the articles in the bath, which is apt to occur if the bath is not in proper working condition; he claims, furthermore, that its addition in either the free or combined state to a solution of nickel salts diminishes the liability to the evolution of hydrogen when the solution is used for the electro-deposition of nickel, and increases the rapidity of deposition, by permitting the use of a more intense current, and improves the character of the deposit by rendering it less brittle and increasing its adhesion.

(To be continued.)

A SUMMARY OF PROGRESS IN SCIENCE AND INDUSTRY, 1883.

[From the Report of the Secretary, January 16, 1884.]

The year just past, though a dull year, was by no means a bad one, since we have had many that were decidedly worse. It was a year of moderate prosperity, characterized chiefly, as it advanced, by a progressive tendency towards a restriction of the consumption of manufactured products, lower prices, and a reduction in wages.

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* Consult U. S. Pat., No. 211,071, December 17, 1878.

My immediate purpose, however, is to present a summary of the industrial progress of the year, and in the following *resumé*, which comprehends only the more important items, a number of matters of interest are considered.

The most noteworthy event of the past year in the field of engineering was the final completion and opening to traffic of the great suspension bridge between New York and Brooklyn, which is universally acknowledged to be one of the unique and most imposing bridge structures of the world. The work was commenced in 1870, and was consequently thirteen years under construction. So much has been said and written concerning this remarkable structure, that any details of its character and dimensions would be a needless repetition. It will suffice to say that it was formally opened to the public on the 24th of May, 1883.

Another notable engineering event was the completion and opening to traffic, during the past year, of a double-track railroad bridge over the Niagara river, about 300 feet above the well-known suspension bridge. The new structure spans a chasm 870 feet wide between the bluffs, and over 200 feet deep. As the stream at this point is a foaming torrent, rendering the construction of piers in the river, or of temporary supports, impossible, it became necessary to design a structure which would be self-supporting during erection; and, to attain this object, it was decided to adopt a bridge of the cantilever type. The structure consists of two steel towers, 132 feet 6½ inches high, resting on stone piers 39 feet high. Each tower supports a cantilever 395 feet $2\frac{5}{16}$ inches long, the shore ends of which are anchored to the abutment masonry, while the river arms are connected by an intermediate span of 120 feet extending from their extremities. The total length of the bridge is 910 feet 4½ inches between the centres of the anchorage piers, the clear span beeween the towers being 470 feet. The height from the surface of the water to the base of the rail is 239 feet. The work of erection occupied but a few months, and it was subjected on completion to a test of unusual severity. It is regarded by those best qualified to pass judgment, as a most successful and creditable piece of engineering. It was constructed to connect the lines of the New York Central and Michigan Central railroads.

Of engineering projects advanced during the past year, perhaps the most interesting to us, is the scheme for the construction of a subway under

Broadway, as a means of relieving the inconveniences resulting from the present overcrowded condition of that thoroughfare. The scheme contemplates a subway street with sidewalks for foot passengers, and railway tracks for passenger and freight traffic. It is proposed to support the upper street upon columns and girders, with arches between, over which the roadbed and pavement will be laid.

The practical completion of another Alpine tunnel, the Arlberg tunnel, in Austria, during the last year, attracted little attention, although its importance is sufficient to warrant special mention of the fact. It is intended to form part of a railway line from Innsbruck on the Tyrol to Bludenz, in the Austrian province of Vorarlberg. The new tunnel is 11,231 yards long. The work will have required, when vaulted and ready to receive the first locomotive, about four years to complete.

The African inland sea project, of which so much has been said and written for the past ten years, has been finally shown to be impracticable. The scheme as originally formulated and ably defended, was to convert the Desert of Sahara into a great arm of the ocean, not unlike the Gulf of Mexico, by which, it was argued, the climate of Northern Africa, and of the contiguous portions of Europe, would be greatly ameliorated, while incidentally great commercial advantages would follow, by thus practically opening the interior of Africa to the commerce of Europe. All this was based on the belief and assumption that the interior of the great desert was a vast natural depression—the bed of an ancient sea—into which the waters of the ocean could be emptied by the simple removal of a coast barrier of inconsiderable magnitude. It has been finally shown that no such basin exists in the interior of the Sahara, and that its principal area is above the level of the Atlantic ocean. Thus this magnificent project is proved to be chimerical.

Of other engineering projects mooted during the past year, I may instance that of a submarine tunnel beneath the Strait of Messina, to connect Italy and Sicily; and a similar scheme to connect Spain with the African coast by a tunnel beneath the Mediterranean sea, concerning neither of which, however, by reason of their magnitude and costliness, is there the slightest probability that they will be undertaken.

It may be of interest to notice incidentally that the endless wire-cable system of drawing street cars, as a substitute for horses, to which I referred in last year's summary, has continued to demonstrate its

feasibility. It has been considerably extended both in San Francisco and Chicago. In Philadelphia, an experimental line, laid down in 1882, proved the advantages of the system so satisfactorily that the projectors have considerably extended it. In Kansas City, a cable road, with duplicate cables and duplicate operating mechanism, to avoid delays or stoppage of traffic, should one of the cables suffer injury, is about to be put in operation.

The work upon the excavation of the interoceanic canal at Panama is reported to have been vigorously carried on during the past year, and the opinion is now generally entertained that the canal will be built in spite of the difficulties interposed by nature.

The English Channel tunnel project seems, for the time at least, to have been allowed to slumber.

I may note at this point, as a matter of incidental interest that the question of increasing the present facilities of the maritime canal at Suez was the subject of much discussion during the past year. The commercial intercourse of Europe with the East has of late been growing so rapidly that for some time past there have been serious complaints of the inadequacy of the present canal, and of the serious delays in the transit of vessels which the constantly increasing traffic through the canal entails. To meet this emergency, two plans have been proposed—namely, to build a second canal along a route substantially parallel to the existing canal, or to considerably enlarge the present canal. Though both of these alternatives have been freely discussed, and the inadequacy of the existing facilities is admitted, considerations of a political nature have thus far proved effectual in delaying action.

Though it is yet too early to obtain the exact figures of the production of iron and steel, we may safely accept the estimates of the Secretary of the American Iron and Steel Association as being approximately true. He estimates the production of pig iron for the past year to have been about equal to that of 1882, in which year it was 4,623,323 gross tons. The total rail production of 1883, according to the same authority, was probably 1,300,000 gross tons, of which about 1,200,000 tons were steel rails, and 100,000 tons were iron rails.

I am enabled, by the courtesy of Mr. Frederick E. Saward, editor of the *Coal Trade Journal*, to give the following estimate of the production of the year 1883. This estimate assumes the total production to have been 93,800,000 tons, divided as follows: anthracite, 31,300,-

000 tons; bituminous, 62,500,000 tons. This estimate exhibits an increase in the figures of total production of about 7,000,000 tons as compared with the ascertained production of 1882.

From the most reliable sources of information, it may be assumed that the amount of new railroad constructed during the year 1883 will make a total of about 6,000 miles. Compared with the extraordinary development of the year 1882, in which the enormous amount of about 11,000 miles were added to the railway systems of the country, the figures for 1883 appear small; but measured by the standard of previous years, it possesses large proportions, since it has only been exceeded in four years, namely, in 1882, 1881, 1880 and in 1872; but, with these exceptions, exceeds the record of all previous years. It was apparent at the close of the year 1882, and the opinion was expressed in my summary for that year, that the rate at which our railway systems was being extended was too rapid to last, and that a notable diminution in mileage was to be expected in the year 1883. The facts above stated have justified this opinion, and evidences are not wanting at this time to warrant the opinion that the present year will witness a still further decline. The most notable event in our railway history during the past year was the completion of the trans-continental line of the Northern Pacific Railroad; while north of our border the Canadian Pacific road was extended to the foot of the Rocky Mountains.

The public interest in the subject of electricity was quite as pronounced during the past year as at any previous time. In the field of electric lighting I have nothing of special interest to record, save to note its steady extension and growth in popularity; and to note the special interest in and attention given to the subject of underground conduits for electric conductors in the streets of our cities. In this direction substantial progress appears to have been made.

The most prominent invention in this department of science which was brought out during the past year, was that of Messrs Delaney and Callahan, of a multiplex system of telegraphy, which, should it realize but a fraction of that which is claimed for it, must work a profound revolution in the art of telegraphy. The system in question is based upon the establishment and maintenance of the practically perfect synchronous rotation of two cylinders—one at each end of the line—with the aid of which a single line wire is placed in communication at both ends simultaneously with corresponding operating instruments, and transferred from one set of such instruments to another, so rapidly

that the operators receiving or transmitting messages are not conscious of any interruption of the circuit. The devices by which the synchronism of the distributing cylinders is maintained are highly ingenious, and entirely automatic, and are affirmed to act so perfectly that for days at a time one instrument will not vary from another by more than the one 600th of a second. Up to the present time the remarkable result has been accomplished, of developing seventy-two separate and independent circuits, adapted to printing telegraph instruments, simultaneously on a single wire, whereby thirty-six different messages may be sent each way, or seventy-two in one direction, or any proportion of this number in either direction, simultaneously over the same wire. The system has been subjected to careful tests, and has secured the unqualified praise of some of our most competent electricians. It is sincerely to be hoped that these flattering commendations may not prove to have been hastily pronounced, by the discovery of some unobserved element of impracticability. Should they prove to be fully justified, the era of cheap telegraphy is at hand.

The remarks of Mr. Weldon, in an address delivered last year before the Society of Chemical Industry in England, would seem to place beyond question the important fact, that the ammonia-soda process is destined to be the process of the future. It has not only made great strides in production in Continental Europe, where at the present time more than half the soda produced is ammonia-soda; but it has even invaded England, the last and greatest strong-hold of the Leblanc soda makers. From 2,500 tons in 1875, the production in England of ammonia-soda had risen to 50,000 tons in 1882, and is steadily on the increase. I have not at hand the figures exhibiting the total production of soda by the two rival processes, but it is an admitted fact that the outlook for the future of the Leblanc manufacturers is gloomy in the extreme, as the new process is not only making progress in England, but is rapidly growing in other countries, notably in Russia, Germany, Austria, and, as I had occasion to remark in last year's summary, in the United States.

The Leblanc soda makers have until lately consoled themselves with the belief that the limited supplies of ammonia—an important element of the newer process—would restrict the production of ammonia-soda. In this they have lately suffered a grievous disappointment, since the last year has witnessed the introduction of a practical procedure for obtaining ammonia in unlimited quantities at comparatively low cost.

The process here referred to, and which, by reason of its direct influence upon the production of soda, and of its ultimate great value to the agricultural interests in cheapening the price of fertilizers, may properly rank as the most important improvement in chemical technology that has lately been made, is neither more or less than the utilization of the ammonia evolved with the waste gases of the iron blast furnaces, and which has hitherto been lost to the chemical manufacturer. The method of ultilizing this ammonia consists simply in scrubbing the waste gases with sulphuric acid, or in fixing it by means of sulphurous or other gaseous acid, and washing out the ammonia salt with water. Several of the Scotch furnaces at which this method of treating their waste gases has been introduced, are said to be producing about a ton of crude sulphate of ammonia daily. From this statement it may readily be believed that in the probable event of the general adoption of the new procedure by the furnacemen of Great Britain, the yield of ammonia could be so enormously increased as not only to meet the demand for it by any possible expansion of the ammonia-soda process, but also to materially aid the agricultural interests, by cheapening the cost of this important fertilizing agent.

The belief gained currency during the past year, chiefly through what proved to be the mistaken opinion of certain eminent persons in England, that the important problem of the cheap production of aluminium had been solved by an English inventor. The publication of the process, unfortunately, dispelled the anticipations of those who have long looked in vain for the process which shall one day enable this metal to play the important role in the arts of civilization for which its valuable properties appear to have intended it.

During the past year much interest was attracted to the question of the availability of sorghum as a source of sugar, especially in view of the alleged adaptability of this plant to the northern States of the Union. The sorghum question has lately been exhaustively investigated by a Committee of the National Academy, which presented an encouraging report upon it, and an experiment upon a scale of considerable magnitude was last year put into full operation in our neighbor State of New Jersey. It is yet too early to pass judgment upon the merits of so important a question, and which involves the domestication of an agricultural industry, for the products of which the United States pays an annual tribute to foreign countries of about $80,000,000.

It is gratifying, however, to be able to record the continued success of the Alverado Beet Sugar Company in California, the only establishment in the United States at present engaged in the manufacture of beet sugar, and to which I made reference last year. The Alverado Company produced last year about 1,500,000 lbs. of beet sugar, and earned large dividends for its stockholders.

The success of this Company in the face of severe competition with the cane sugar of the Hawaiian Islands, which existing treaty provisions with that kingdom admit free of duty, is especially noteworthy. It effectually disposes of the notion that there is any insuperable obstacle in the way of the profitable introduction of this industry in the United States, and lends strong probability to the views entertained by those most competent to express an opinion, that the failures that have overtaken similar enterprises started in other States, were due to inadequate capital, incompetent management, or to both causes combined.

The energetic measures taken during the past year by Stanley and De Brazza, in their efforts to bring about a more direct commercial intercourse between Europe and the populous interior of the African continent, by establishing trading posts along the course of the river Congo, are worthy of special mention. Of interest, also, is the exploring expedition undertaken by Nordenskjold, to determine the character of the interior of the continent of Greenland. The results of this expedition, which have lately been published, though most disappointing to this indefatigable explorer, may be considered to have demonstrated the fact, that the vast interior of this hitherto unknown continent is a desert of perpetual ice.

A subject that should not be overlooked, because of its possible future industrial importance, is the discovery of tin ore in apparently considerable quantities in several localities in the United States, during the past year. Of these discoveries, one at least is so well authenticated that its value may be considered as placed beyond question. I refer to the announcement last year, by Prof. Wm. P. Blake, of the existence of ore desposits of this important metal of considerable extent in the region of the Black Hills of Dakotah. When it is considered that thus far not a single ton of tin is produced in the United States, and that we have imported tin plates alone to the value of \$100,000,000, from England, during the past ten years, the importance

of developing domestic sources of supply of this indispensible metal, that promise to relieve the country of paying so large an annual tribute to foreign manufacturers, will be appreciated.

One of the most practical and far-reaching reforms introduced during the past year, was the adoption of a uniform system of standard time throughout the United States, and which has most satisfactorily done away with the annoyances and confusion arising from the almost innumerable local time standards hitherto in vogue. This reform, by almost unanimous concurrence of the government departments, municipal and town authorities, railroad companies and other influential corporations of the country, went into practical effect in the month of November, 1883. The plan of the new system, the suggestion and final adoption of which are due to Professors Abbé and Barnard, consists, briefly stated, in dividing the territory of the United States, which is comprised between the 50th and 130th degree of longitude west from Greenwich, into sections of 15 degrees each, and requiring all localities lying $7\frac{1}{2}$ degrees east and west of the controlling meridian of that section to conform their time to that of this meridian. This arrangement not only introduces uniform time in each of the sections, but it makes the minutes and seconds on all the standard clocks identical, the hour hand alone showing a difference. The controlling meridians are the 60th, the 75th, the 90th, the 105th, and the 120th, giving to all localities lying within $7\frac{1}{2}$ degrees east and west of each, respectively, its time; and the time of the five sections thus established is designated as Eastern, Atlantic, Valley, Mountain and Pacific time, and the standard time of the localities included in these sections differs by just one hour from that of its neighboring section—slower than that on its eastern border, and faster than that on its western border.

The past year will long be memorable in the United States as a year of floods of unprecedented magnitude, and of tornadoes of unparalleled violence. From both of these causes the destruction of life and property was very great. Other portions of the world were visited by siesmic disturbances of great energy and destructiveness, notably the islands of Ischia and Java. The outbreak in the latter island was attended with such destruction of life, and by such profound alterations of the topography of the country, and of the adjacent sea bottom, that competent authorities agree in pronouncing it to have been the most greatest disturbance of its kind that has occurred within the historic toric period.

PROPOSED ORDINANCE FOR THE EXAMINATION OF STEAM ENGINEERS.

At the stated meeting of the Franklin Institute, held Wednesday, October 17, 1883, Mr. J. W. Nystrom offered the following preamble and resolution, viz.:

To the President and Members of the Franklin Institute.

WHEREAS, The City of Philadelphia has suffered a great many disastrous steam boiler explosions which could have been prevented by proper precautions, and

WHEREAS, There are now in use in the City of Philadelphia some six hundred boilers which have dangerous flat cast iron heads, any one of which is liable to explode at any moment if in charge of incompetent attendants, and

WHEREAS, So great a number of dangerous steam boilers cannot reasonably be removed without great inconvenience and expense to the owners of these boilers, and

WHEREAS, It is known that the explosions of this class of boilers have been caused by incompetent attendants, be it

Resolved, That the Mayor and Select and Common Councils of the City of Philadelphia be respectfully requested by the Franklin Institute to pass an Ordinance to the following effect, viz.:

Supplement to an Ordinance of July 13, 1868, *entitled "An Ordinance regulating the Inspection of Steam Boilers in and for the City of Philadelphia, Pennsylvania.*

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That from and after the 1st day of January, 1884, all engines and steam boilers operated in the City of Philadelphia shall be run and in charge of such engineers only as shall be furnished with a proper certificate as hereinafter provided.

SEC. 2. The Chief City Inspector is hereby authorized and required to designate the time and place when and where all applicants for a certificate shall be entitled to apply for examination and shall receive a certificate if found to be competent. For this purpose the said Chief Inspector shall sit at least once a month.

SEC. 3. He shall issue certificates of two classes—the first to such parties as may in his judgment be qualified to have charge of an engine and boilers, the second, to such as may in his judgment be qualified to have charge of steam boilers in establishments where no engine is used.

SEC. 4. For these certificates, which shall be issued for one year, each party receiving the same shall pay a fee of two dollars for first-class, and of one dollar for second-class certificate.

SEC. 5. That the said City Inspector shall refuse to grant a certificate of inspection to any person who shall maintain or keep in use or operation, or shall put in use or operation, any stationary steam engine or boiler within the said City of Philadelphia, which shall not be in charge of an engineer duly furnished with an engineer's certificate as aforesaid.

SEC. 6. That whenever the said City Inspector shall learn of any boiler or engine being operated otherwise than by an engineer duly qualified and furnished with a certificate as aforesaid, he shall forthwith cancel and revoke his certificate of inspection. And the certificate of inspection of any steam-user who shall thus attempt to operate an engine or boiler without the care of an engineer furnished with a proper certificate shall be deemed and adjudged forfeited, and such steam-user shall be subject to all the pains and penalties provided by Act of Assembly of May 7, 1864.

JOHN W. NYSTROM.

On motion of Mr. Nystrom, the preamble and resolution were referred to a special committee. The President appointed Messrs. J. W. Nystrom, Washington Jones, C. M. Cresson, Coleman Sellers, Jr., Thomas Hockley, Esq.

In conformity with a resolution adopted at the stated meeting held November 21, 1883, the President increased the above-named committee by the addition of Messrs. William Helme and William A. Ingham.

At the stated meeting held December 19, 1883, the committee presented majority and minority reports, which were ordered to be printed for the use of members. In compliance with this order, the same are herewith submitted.

WILLIAM H. WAHL,
Secretary.

MAJORITY REPORT.

To the President and Members of the Franklin Institute.

GENTLEMEN:—Your Committee to whom was referred the resolutions relating to the "Examination and Licensing of Engineers by a

Board to be appointed by the City Authorities," presented at the meeting held October 17th, 1883, respectfully reports:

It is not advisable to ask for the passage of an ordinance requiring persons who have charge of engines to pass an examination and be licensed by a Board. Such an ordinance would be in restraint of liberty, and should never be enacted unless a free system is intolerable, or unless the reasons for restraint are shown to be overwhelming. Every security possible should be extended to life and property, but the undersigned are of the opinion that the proposed ordinance would not tend to increase it, for the following reasons:

First. The qualifications of an engineer, as to sobriety, watchfulness, application to his duties and a knowledge of the machine under his care cannot be determined by a Board of examiners, but can be, as now, by his employer.

Second. As the examinations must necessarily be upon the same few points, it might be possible for incompetent candidates to become possessed improperly of the correct answers to the questions, and consequently receive a license without possessing the qualifications of an engineer.

Third. The passage of such an ordinance would create a privileged class of men with power to fix their own wages regardless of the value of the service rendered, and, as proprietors, would be compelled by law to employ only those having a license, it would assist in extending an odious feature of Trades' Unionism.

Fourth. Should loss of life or damage to property be caused by an exploding boiler, whilst in charge of an engineer licensed by municipal authority, it is a question whether the responsibility would not be removed from the proprietor and placed upon the city.

Fifth. It is not within the scope of an Institution formed for the promotion of the Mechanic Arts to recommend or induce legislation upon matters not relating to its purpose.

WASHINGTON JONES,
WM. HELME,
COLEMAN SELLERS, JR.,
CHARLES M. CRESSON, M.D.

I concur in the above report except as to paragraphs, Nos. 4 and 5.

THOMAS HOCKLEY.

MINORITY REPORT.

PHILADELPHIA, Nov. 19, 1883.

To the President and Members of the Franklin Institute:

GENTLEMEN:—The Special Committee to whom was referred the preamble and resolution in the matter of petitioning the Mayor and Councils of Philadelphia to pass an ordinance for examining stationary engineers and firemen, respectfully report

That the Committee is of the opinion that it would be of great advantage to the city of Philadelphia, as well as to steam-users therein, in regard to safety and economy in the working of stationary steam engines and steam boilers, to create a spirit of emulation among engineers and firemen, by classing them into grades by strict examination.

The Committee also believe that the examination of stationary engineers is of equal importance to that of steam boiler inspection and to the examination of steamboat engineers, and that it would be expedient to enforce strict examination of all stationary engineers in the State of Pennsylvania by an Act of Assembly.

According to the Census Report of 1883, there are 7,913 steam engines, aggregating 512,408 horse-power, in the State of Pennsylvania.

There are about 1,700 engineers in charge of stationary steam engines and steam boilers in the city of Philadelphia, of whom only 250 have certificates of competency.

The originally proposed ordinance, published in the November number of the JOURNAL, was found to be defective and incomplete for fully attaining its high purpose, and it has therefore been amended in hope that the Institute will approve its recommendation to the City Councils for adoption.

The City Councils have full power under the existing Acts of Assembly to pass the proposed ordinance, as will be seen by the following.

The Act of Assembly of May 7, 1864, for regulating steam boiler inspection, says on page 880 Pamphlet laws:

"SECTION 3. The Councils of the City of Philadelphia shall have power to make all needful rules and regulations for the purpose of carrying the foregoing provisions into effect, and shall provide such other regulations as may be necessary to carry into effect the provisions of this Act and they may provide for the performance of the

duties, hereinbefore enjoined, by deputies, or other assistants of said inspector, as they may deem necessary."

This section makes it very clear that the proposed ordinance for examining engineers is one of "such other regulations" which is found to be necessary for carrying steam boiler inspection into effect. For, if the steam boiler is in charge of an incompetent attendant, the inspection is of no use, as has been proven by explosions of inspected boilers.

The City Councils have already passed an ordinance similar to the proposed one, namely, that of July 13, 1868, for regulating steam boiler inspection, which says, page 331:

"SECTION 11. If at any time the Inspector shall deem the engine-driver incompetent or unreliable, he may withhold or withdraw his certificate (of inspection). The inspector shall report to a magistrate and have bound over for trial any person or persons who may have rendered themselves liable by infraction of any provision of this ordinance, as provided in Section 4 of the Act of Assembly of May 7, 1864."

The question here arises, how can the Inspector find out if an engineer is incompetent without having first examined him? Or, is the Inspector to wait until the engineer has committed some blunders and caused steam boiler explosions with destruction of life and property, before considering him incompetent?

When the City Councils have power to pass the ordinance of July 13, 1868, with the Section 11, then they have also power to pass the proposed ordinance for examining engineers.

The Committee objects to the use of the term "engine-driver" as improper, for the reason that it is the steam which drives the engine, and not the engineer.

The question with the Franklin Institute in this matter is not that of law, which is for the City Councils to ask the City Solicitor, but whether or not it would be expedient for the City Councils to pass the proposed ordinance; for, in case they had not the power to pass it, such could readily be obtained by an Act of Assembly.

With the above considerations, the Committee respectfully recommends that the Franklin Institute shall take this forward step in the advancement of steam engineering, namely, to adopt this report, and submit it in full, with the preamble and resolution, to the City Councils, with recommendation for the passage of the proposed ordinance for examining stationary engineers.

JOHN W. NYSTROM, *Chairman.*

The following is the amended form of the proposed ordinance, referred to in the minority report:

PREAMBLE.

WHEREAS, The City of Philadelphia has suffered a great many disastrous steam boiler explosions which could have been prevented by proper precautions, and

WHEREAS, There are now in use in the City of Philadelphia some six hundred boilers which have dangerous flat cast iron heads, and other defects, and

WHEREAS, Any one of these boilers is liable to explode at any moment if in charge of incompetent attendants, and

WHEREAS, So great a number of dangerous steam boilers cannot reasonably be removed without great inconvenience and expense to the owners of these boilers, and

WHEREAS, It is known that the explosions of this class as well as of other classes of boilers have been caused by incompetent attendants, and

WHEREAS, It is of equal importance to examine stationary engineers as it is to examine steamboat engineers, for the reason that human life is as precious on land as on water, and

WHEREAS, It has been demonstrated by explosions that the object of steam boiler inspection cannot be rendered effective without competent attendants, and

WHEREAS, It has been proven by experience that it is necessary to examine steamboat engineers in order to render steam boiler inspection effective, and

WHEREAS, It would be of great advantage to the City of Philadelphia as well as to the steam users therein, in regard to safety and economy in the working of steam engines and boilers, to elevate stationary engineers by examination and grades, to the level of steamboat engineers, be it

Resolved, That the Mayor and City Councils of the City of Philadelphia be respectfully requested by the FRANKLIN INSTITUTE to pass an Ordinance to the following effect, viz.:

Supplement to an Ordinance of July 13, 1868, *entitled an Ordinance regulating the inspection of Steam Boilers in and for the City of Philadelphia, Pennsylvania.*

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain:* That from and after the first day of January, 1884, all Engineers and Firemen who have charge of stationary steam engines and steam boilers operated in the City of Philadelphia shall apply to the City Chief Boiler Inspector, for certificate of competency as hereinafter provided.

SECTION 2. The City Chief Boiler Inspector is hereby authorized and

required to designate a time and place when and where all applicants for certificate shall be entitled to apply for examination, and shall receive a certificate if found to be competent and of good standing. For this purpose the said Inspector shall sit at least once a month.

SECTION 3. That the said City Inspector shall have an assistant Examiner, whose duty shall also be to keep records of qualification and standing of each Stationary Engineer and Fireman who hold certificate of competency, and that each candidate shall be examined by both the said City Inspector and his assistant Examiner, and both to sign the certificate if found to be competent.

SECTION 4. That the said City Inspector shall issue certificates of five different classes, namely, as follows:

First Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working of engines and boilers for a term of not less than ten years, and can pass a thorough examination in the practical management and care of stationary steam engines and steam boilers; in the rudiments of the sciences involved in his profession, such as elements of mechanics; properties of water and steam in relation to heat; properties of different kinds of coal in relation to combustion and its economy; in the construction and properties of different kinds of stationary engines and boilers; in the properties and uses of steam indicators and indicator diagrams; and in the principal causes and prevention of steam boiler explosions. Any candidate who is found by examination to be worthy of a first class certificate shall be distinguished thereon as Chief Engineer.

Second Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working of stationary steam engines and steam boilers for a term of not less than five years, and can pass a thorough examination in the practical management and care of stationary steam engines and steam boilers, including the taking of, and working out indicator diagrams, and in the principal causes of steam boiler explosions.

Third Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working and care of stationary steam engines and steam boilers for a term of not less than two years, and can pass a thorough examination in the practical management and care of such engines and boilers, and in the principal causes of steam boiler explosions.

Fourth Class Certificate shall be issued to any applicant whom the Examiners find competent to take charge of stationary steam engines and steam boilers of horse-power not exceeding that which shall be stated on the certificate.

Fifth Class Certificate shall be issued to any Fireman whom the Examiners find competent to take charge of stationary steam boilers used for heating purposes in manufacturing establishments where no steam engine is used.

SECTION 5. For these certificates each party receiving the same shall pay a fee as follows:

First Class Certificate, five dollars.

Second Class Certificate, four dollars.

Third Class Certificate, three dollars.

Fourth Class Certificate, two dollars.

Fifth Class Certificate, one dollar.

SECTION 6. All moneys collected as fees by said Inspector for aforesaid certificates shall be paid over to the City Treasurer, and the City Controller shall audit the accounts annually.

SECTION 7. That during the first six months of the year 1884, the time in which this Ordinance shall be brought into full effect, such Stationary Engineers and Firemen, who are well known to the said City Inspector, or to his assistant Inspectors or Examiner, to be competent and of good standing, may receive a third, fourth, or fifth class certificate without examination, but after the expiration of said six months, that is, on or after the first day of July, 1884, every applicant must be thoroughly examined as aforesaid, before receiving a certificate of competency.

SECTION 8. That on and after the first day of July, 1884, all stationary steam engines and steam boilers operated in the City of Philadelphia, shall be run and in charge of only such Stationary Engineers as shall be furnished with proper certificate of competency as before provided.

SECTION 9. That when any Engineer or Fireman who has received a certificate, is afterward found to be incompetent or negligent in his duty, the said City Inspector may cancel and revoke such certificate, and he may by re-examination issue to such Engineer or Fireman another certificate, but of a lower class to an Engineer.

SECTION 10. That the said City Inspector shall refuse to grant certificate of inspection to any party who shall maintain or keep in use or operation any stationary steam engine or steam boiler within said City of Philadelphia, which shall not be in charge of an Engineer duly furnished with a certificate of competency as aforesaid.

SECTION 11. That whenever the said City Inspector shall learn of any stationary steam engine or steam boiler being operated within the said City of Philadelphia otherwise than by an Engineer duly qualified and furnished with a certificate as aforesaid, he shall forthwith cancel and revoke his certificate of inspection.

SECTION 12. That the certificate of inspection held by any steam user who shall attempt to operate a steam engine or steam boiler without the care of an Engineer furnished with a proper certificate of competency shall be deemed and adjudged forfeited, and such steam user shall be subject to all the pains and penalties provided by the Act of Assembly of May 7, 1864.

SECTION 13. That nothing in this Ordinance shall be so construed as to render the City of Philadelphia responsible for any damage caused by steam boiler explosion or other accident occurring from neglect or incompetency of any Engineer or Fireman who may have passed his examination, and received a certificate of competency from the proper authorities.

SECTION 14. All Ordinances or parts of Ordinances inconsistant herewith are hereby repealed.

Celestial Photography.—The first application of photography to astronomy was made in France. The first Daguerrian image of a heavenly body was that of the sun, which was taken by Fizeau and Foucault, April 2, 1845. Soon afterwards fine photographs of the moon were obtained, in the United States by Rutherfurd, and in England by Warren de la Rue. In many observatories photographs of the sun have been taken for twenty years, to facilitate the study of the spots and faculæ. More recently still, Rutherfurd and Gould photographed the stars, for the purpose of forming celestial charts, and Draper obtained a successful photograph of the great nebula of Orion. The large solar images, which have been obtained during the last few years at Meudon, have revealed phenomena on the sun's surface which are invisible to the most powerful telescopes, and which open an entirely new field of research. By their aid we learn the true form of those elements of the photosphere about which so many different and contradictory assertions have been hazarded. In 1881, the first photograph of a comet with its tail was obtained at Meudon. It revealed curious details of structure and allowed divers photometric measurements, which showed that the tail, in spite of its apparent brilliancy, is from two to three hundred thousand times less luminous than the moon. The preservation of the images, the wide range of sensitiveness in the plates, and the faculty of embracing the most feeble as well as the most powerful luminous phenomena, lead Janssen to style the photographic plate the true retina of the savant.—*L'Astronomie*, April, '83.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, January* 16, 1884.]

Hall of the Institute, Jan. 16, 1884.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

Present, 90 members and 5 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, January 9th, 11 persons had been elected to membership. He also presented the following

Annual Report of the Board of Managers for the year 1883.

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute during the year 1883.

During the year 139 new members have been elected; 22 have resigned; and 49 have been dropped for non-payment of dues.

The following is a condensed summary of the report of the Treasurer for the year ending December 31, 1883.

RECEIPTS.

Balance on hand, January 1, 1883	$ 1,931 65	
Cash received from Philadelphia and Reading Railroad bond ($1,000)	1,135 00	
Cash received from all other sources	13,844 99	
Total		$16,911 64

PAYMENTS.

Five per cent. Building Loan paid off	$ 136 25	
Six shares Pennsylvania Railroad stock	300 00	
Pennsylvania Railroad scrip bought to make even amounts to take 12 shares	44 46	
Exhibition of 1884	307 71	
All other current payments	15,465 65	
		$16,254 07
Balance on hand, December 31, 1883		657 57
Total		$16,911 64

The accounts show a diminution in cash balance of	$1,274 08
" " " securities of	251 75
Deficit for 1883	$1,525 83

Which is more than balanced by the increased value of the Library and other property of the Institute.

The increase of the Library during the year 1883, owing to the increased appropriation by the Board, aided very materially by the judicious activity of your Committee, has been greater than in any previous year, the total additions being over 3,000 volumes and pam-

phlets. The Board refers to the Report of the Committee on the Library for the details.

The Board feels impelled to repeat what has been said in previous reports, that the accommodations of the Library are entirely insufficient. New cases have been added and filled, and more ordered, but notwithstanding this, the Librarian is compelled to adopt the plan of doubling the volumes of scientific serials upon the shelves in the cases where they belong. The Board feels also compelled to denounce an evil, partly owing to present inconvenient arrangements which make it impossible for the guardian in charge to oversee the whole Library. It has been discovered that unprincipled persons have cut out pages and illustrations of books, and thus some of our sets have been mutilated, and it is impossible to know to what extent this has been done.

The progress of the JOURNAL has been satisfactory. The general index is far advanced, and is expected to be finished during the present year.

During the present year, thirty-five lectures were delivered under the direction of the Committee on Instruction, with the aid and counsel of the Professors. They were divided as follows: Prof. H. C. Lewis, two lectures on Geology; Mr. C. Henry Roney, four on Sanitary Engineering; Dr. H. F. Formad, five on the Smallest Living Organisms; Prof. A. J. Parker, five on the Sensory Organs; Dr. C. B. Dudley, two on Friction and Lubrication; Mr. Thos. H. McCollin, two on Photography; Prof. Persifor Frazer, two lectures introductory to the course on Chemistry; Prof. Coleman Sellers, one lecture introductory to the course on Mechanics; Mr. Joshua Rose, five lectures on Tools; Prof. W. H. Greene, four on Chemistry; Dr. C. Fahlberg, one on Technical Chemistry; Prof. E. J. Houston, a Christmas lecture to the children.

In addition to the above in the regular course, Mr. James Platt, of Gloucester, England, delivered, by invitation, a lecture on Hydraulic Machines as Applied to Riveting Boilers and Ships; and Edweard Muybridge, of San Francisco, one on the Attitudes of Animals in Motion.

The attendance at these lectures was uniformly good. The policy of issuing free tickets, to members for distribution to friends has been continued, and seems to give entire satisfaction.

The Drawing School, which still continues under the direction of Mr. William H. Thorne, has, in point of discipline, effectiveness of

instruction, and number of pupils in attendance, made gratifying progress.

The pupils in attendance at the spring term numbered 192, and those at the winter term, 184, making a total of 376. They were divided into seven classes with one instructor to each class. The school is now very efficiently organized and officered, and your Board refers to this branch of the Institute's work with satisfaction. The entire third story of the Institute building is now given up to the school, and its further growth will, therefore, be checked for want of additional class-rooms.

The last annual report of the Board contained a suggestion of a special Exhibition of Electricity and its applications. In execution of this design, the Board has caused all the necessary preliminary steps to be taken. In order to present the subject completely, it was decided to make the Exhibition international, and to that end a joint resolution of Congress was obtained to admit duty free all foreign contributions to the Exhibition. The free use of the lot at the corner of Thirty-second street and Lancaster avenue has been secured from the Pennsylvania Railroad Company, and the various sub-committees of the Committee on Exhibitions have completed the preparation of the papers to be issued both in this country and in Europe. The opening of the Exhibition has been fixed for Tuesday, September 2, 1884; and from the interest generally manifested in the subject, the Board has the confident hope that the Exhibition may prove of the greatest benefit to all concerned.

The American Association for the Advancement of Science has determined to hold its session for 1884 in this city during the month of September. The British Association, which is this year to hold its annual session in Montreal during the month of August, will then have adjourned, and it is hoped that a large number of scientific men may be in this city during the Exhibition.

To reap the full benefit of these circumstances, a committee was appointed by the Institute, at the September meeting, to arrange, if possible, for an Electrical Conference to convene in Philadelphia upon the occasion. This committee has been actively engaged in correspondence upon the subject, and has met with the cordial sympathy of distinguished men. A bill has been introduced into Congress, providing for the appointment of a National Scientific Commission to conduct the Electrical Conference, and appropriating a small sum to

defray the necessary expenses of conducting the investigations, reporting the proceedings, and publishing the results of the Conference.

The Board indulges the hope that this movement may be successful, and that so excellent an opportunity for the advancement of Science may not be thrown away.

The Chemical and Electrical Sections and the Phonetic Short-hand Section have exhibited a creditable degree of activity during the past year, and your Board refers to their reports with satisfaction.

The Committee on Science and the Arts, during the past year, has reported upon twenty-three applications, and in nine cases, has recommended the award of the John Scott Legacy Medal and Premium, all of which were confirmed by the Institute, and approved by the Board of City Trusts.

All of which is respectfully submitted.

By order of the Board,

W. P. TATHAM, *President.*

January 9, 1884.

The Committee on the Library presented the following Report:

Total number of volumes in Library, Dec. 30, 1882 (exclusive of pamphlets), as per last report, 16,776.

Additions in 1883.	Pamphlets.	Unbound.	Bound.
Bound volumes, purchased out of general appropriation			106
Unbound " " " "		13	
Pamphlets, " " "	80		
Bound volumes, purchased from JOURNAL			[illegible]
Pamphlets, " "	1		
Bound volumes (B. H. Moore fund)			111
Unbound " "		4	
Bound " donated			610
Unbound " "		20	
Pamphlets, "	1,398		
Exchanges for duplicates			129
Exchanges, bound in volumes			134
Volumes other than exchanges, bound			[illegible]
Rebound			[illegible]
Total	1,479	[illegible]	1,188

Total number of volumes in Library, Dec. 31, 1883, 18,262, exclusive of pamphlets, which (although no actual count has been made as yet) it is estimated, number about 9,000.

Of the books purchased, fifty volumes and one pamphlet, valued at about $110.00, were received from the JOURNAL of the Institute, to which they were sent for review.

Duplicates.—90 volumes and pamphlets, valued at $116.00, were exchanged for 139 volumes and pamphlets, valued at $128.00.

222 volumes and pamphlets have been presented to the Library by various Departments of the U. S. Government, and 95 (needed to fill gaps in serials) were purchased, at an expense of about $35.00.

Among the books presented are several volumes of American Ephemeris and Nautical Almanac (the publication office of which had omitted the name of our Library for the last two years); Reports of the Hayden Survey; Reports of Consuls upon the Commercial Relations with the United States (monthly publications, which will be sent regularly in the future); Reports of Director of U. S. Mint; Professional Papers of U. S. Signal Service (to be sent regularly in future); Navy Scientific Papers.

An exchange was effected with the U. S. Geological Survey Office for all future publications of that office, and the name of the Library placed on the distributing lists of a number of Bureaus in the Departments of the Government. During the last two months, correspondence has been opened with over 400 engineers and superintendents of water departments of cities of over 10,000 inhabitants for their reports, and your Library is now in possession of these. In many instances complete sets were obtained, which, for want of time to arrange, cannot be included in the list of serials completed during the year 1883.

Among donations received may also be mentioned, Dictionnaire des Jardinieres (deposited by Dr. A. J. Brazier in 1851, and presented to the Library by his sister, as per request of the deceased); a second invoice of books from the executor of the late John Lenthall, U. S. Navy, including the Transactions of the Institution of Naval Architects, with Index to first 21 volumes; Reed's Ship Building; Rankine's Ship Building, and many French works upon the same subject. Also, nine volumes of Poor's Railway Manual, valued at $45.00; ten volumes of Proceedings of American Pharmaceutical Association; a number of volumes of Journal of American Geographical Society,

from the Society; Journals of Select and Common Councils of Philadelphia, from Charles H. Banes; and Proceedings of the American Association for the Advancement of Science.

Exchanges.—108 foreign, 85 domestic and 20 city, or a total of 213 weekly, monthly and daily journals have been received in the Library during the past year in exchange for the JOURNAL of the Institute.

Serial Publications.—Sixty-one serial publications and four sets of scientific works have been completed during the year. Among them may be named: The Philosophical Magazine from 1796 (as Nicholson's Journal) to 1883, including all its branches; Newton's London Journal of Arts and Sciences; Transactions of Society of Arts, London; Journal of Society of Arts, London; Transactions of Institute of Naval Architecture of Great Britain; Proceedings of American Pharmaceutical Association; Canadian Naturalist and Geologist; Journal of American Geographical Society; American Association of Geologists and Naturalists; Civil Engineer and Architect's Journal, London; Reports on the Geology of Pennsylvania; Reports of Geological Survey of Kentucky, 1st series.

The accompanying table shows the additions of all kinds made to the Library each year since 1875, the date of the first published report:

Year.	Bound.	Unb. and Pamphlts.	Total.
1875	1,607	158	1,76[illegible]
1876	1,418	408	1,82[illegible]
1877	915	[illegible]	[illegible]
1878	655	[illegible]	[illegible]
1879	1,201	1,8[illegible]	[illegible]
1880	[illegible]	840	1,[illegible]
1881	[illegible]	[illegible]	1,161
1882	808	478	1,2[illegible]
1883	1,0[illegible]	1,728	[illegible]
	9,168	[illegible]	18,5[illegible]

Respectfully submitted.

CHAS. BULLOCK,

Ch'n Committee on Library.

The Trustee of the Pennsylvania Museum and School of Industrial Art presented the following Report:

To the President and Members of the Franklin Institute:

Your representative in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, herewith presents a summary of the operations of the Institution during the past year, viz.:

The number of admissions to the Museum in Memorial Hall, during the year was 168,931, being an increase of 9,648 over the year 1882.

The greatest number admitted in any one month was 30,465 in September, and the greatest number in one day was 4,323 on September 9th.

The steady increase in the number of visitors, which these figures exhibit, may safely be taken as an evidence of the growing popularity of the Institution.

The chief events in the history of the institution during the past year, are, the transfer to the Smithsonian Institution of the collection of the American Institute of Mining Engineers, the gift by Mrs. Bloomfield H. Moore, of eighty-two (82) large oil paintings (apparently old, and copies of old masters, but as no catalogue has been received to date, their authorship is unknown). The Museum made no purchases during the past year. One hundred and sixty-seven (167) objects were received by donation, and four hundred and thirty-seven were reeeived on loan. The additions to the Library numbered twenty.

The School of Industrial Art, which is very properly regarded as the most important branch of the Institution's work, was continued during the past year at the rooms No. 1709 Chestnut street, under the same general direction as during 1882; the number of pupils averaged eighty-two (82).

The financial embarassments which for several years seriously hampered the proper development and usefulness of the Institution, were happily removed during the past year. By the active co-operation of the old Centennial Executive Committee of Women, under the name of the Associate Committee of Women, a very successful entertainment was given on December 12th, at the Academy of Music, for the benefit of the Endowment Fund, and which netted four thousand five hundred (4,500) dollars.

The Endowment Fund at present amounts to about fifty-five thou-

sand (55,000) dollars, all of which was definitively secured during the past year.

The Institution enters upon the present year with much ampler opportunities for usefulness than ever before.

Respectfully submitted,

WILLIAM H. WAHL.

Philadelphia, January 16, 1884.

Reports were also presented from the Chemical, Electrical and Phonetic Short-hand Sections.

All of the above were accepted.

The Tellers of the annual election held this day, between the hours of 4 and 8 P. M., made their report, whereupon the President announced the following as the result, viz.:

President (to serve one year), Wm. P. Tatham.

Vice-President (to serve three years), Charles Bullock.

Secretary (to serve one year), William H. Wahl.

Treasurer (to serve one year), Samuel Sartain.

Managers (to serve for three years), Washington Jones; Pliny E. Chace; Joseph M. Wilson; Coleman Sellers; Theo. D. Rand; A. E. Outerbridge, Jr.; Isaac Norris, M. D.; C. Chabot.

Manager (for one year in place of Wm. V. McKean, resigned), Chas. J. Shain.

Auditor (to serve three years), Lewis S. Ware.

Representative in the Pennsylvania Museum and School of Industrial Art (to serve one year), William H. Wahl.

A vote of thanks to the Tellers was unanimously passed.

The Secretary's Report embraced a *resumé* of progress in Science and Industry for the year 1883, published elsewhere in the JOURNAL; and a description of the following mechanical inventions, viz.:

An Improved Locomotive Headlight, of Post & Co., Cincinnati, in which the front glass is convex and provided with hinged transparent color signals, which, owing to the convexity of the front glass, can be seen from front, side or rear. The reflector is so pivoted as to permit its being turned through 90°, so that the lamp can be lighted from the side door instead of opening the front of the case. There is also a convenient match-striker. The lamp reservoir is removable for

filling, as in the "St. Germain" (generally miscalled "German") student's lamp.

A Rail Joint, shown on behalf of W. F. Gould, of Des Moines, Iowa, and consisting of a base piece which rests under the flange, and on one side follows round it, and up the web. It is held laterally by one or more two-part clamps passing under and around the base piece, and holding all firmly together by a single bolt and nut. This joint can be used to splice broken rails, and requires no drilling of the rail. For a suspension joint, the chair is used with one clamp; and for a tie-joint, the chair and two clamps.

William Briscoe's plan for removing snow from streets, consisting of the usual sweeper-car, in conjunction with an endless elevator, for conveying the snow into a furnace, heated by a hot blast, in which it is to be melted, and from which it is allowed to run out at convenient intervals.

Lindsey Rossiter's Improvement in Car and Vehicle Axle Boxes, a description of which would not be intelligible without illustrations.

Mr. S. Lloyd Wiegand thereupon read a paper on "Cast Iron in Steam Boilers," which will appear in the JOURNAL. It was discussed by Messrs. W. B. Le Van, N. B. Williames, Wm. Helme and the author.

The consideration of the subject of the proposed "Ordinance for the Examination of Steam Engineers" was then taken up. The majority and minority reports, and the amended form of ordinance presented as a portion of the latter appear elsewhere in the JOURNAL. The subject was very freely discussed by Messrs. Wm. Helme, H. Orr, J. W. Nystrom, Wm. B. LeVan, Washington Jones, G. M. Eldridge, and Wm. B. Cooper; and on motion of the last named, seconded by Mr. G. M. Eldridge, both reports were laid on the table.

Under New Business, Mr. Wiegand offered the following:

Resolved, That the Committee on Science and the Arts, be requested to ascertain and report the properties and strength of cast iron, as a material for the construction of boiler-heads and other vessels for retaining fluid under pressure, together with such rules for estimating the strength and proportioning of such structures, in the different forms now in use, with economy and safety, and also the proper modes of testing and using such structures, as will be useful to those practically engaged in the manufacture and use thereof.

The resolution was carried.

Adjourned.

WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVII. MARCH, 1884. No. 3.

MECHANICS—INTRODUCTORY.

By Prof. COLEMAN SELLERS.

[Delivered at the opening of the course of lectures on Mechanics, Friday, November 9, 1883. Revised from report of Phonographer.]

LADIES AND GENTLEMEN:—The order of lectures that has been announced for the season of 1883–1884, calls for one by me, noted as "Introductory on Mechanics," rather an indefinite title I admit, but I do not want you to expect a formal lecture on Mechanics; I desire to speak in the first place about the lecture course and about methods of instruction. Bear in mind please, that about sixty years have passed since the first lecture was delivered before the Franklin Institute. It was on the 28th of April, 1824. At that time our Institute had no abiding place. Through the courtesy of the Trustees of the University of Pennsylvania, the old academy on south Fourth street was loaned to the Institute and many of its lectures were delivered there. The first course was a series on Mechanics, Natural Philosophy and Chemistry, and Architecture, it was attended mainly by members, sons of members and apprentices who desired information that could not be obtained at that time in the public school. To these early lectures no women were admitted. It was not until the second course, when lectures on Natural History were added to the list, I presume by Dr. Godman, that women were admitted to these lectures on Natural History; and from that time to the present nearly all lectures have been honored by their presence. It is very pleasant to think that so many

of them desire the kind of instruction that has been given in this place.

If we consider what was the state of the Arts at the time the Franklin Institute was organized, and what the state of the Arts now is, we can form a better idea of what lecture courses were best adapted to the wants of the members in those days, and what is expected of the lectures of the present day.

In business, we may measure the success of mechanical enterprise by the success of the railroads. When railroads are doing a paying business the mechanic arts are prosperous. I think it may be very well to take the railroad as the standard of the progress of the United States during the sixty years that have elapsed since the first Franklin Institute lecture was delivered. Let us glance backwards to the condition of the railroads sixty years ago. It was in 1824 George Stevenson one of many active workers in the same direction, began his earnest work to induce the people of England to build the Liverpool and Manchester Railroad. In 1825 he was laughed at for his wild scheme. We can find in books in some libraries an account of the bubbles talked of in 1825, among which was a contemplated railroad from Liverpool to Manchester. The term locomotive as the name is now applied to a machine was not then invented. It was not until 1829, within the lifetime of many who are now present, that the first railroad for freight and passengers operated by steam was opened. Before that time, Oliver Evans, in 1804, it is true, carried through the streets of Philadelphia, a dredging scow and propelled it on land and water by steam. Oliver Evans died in 1819. And Hedley had proposed smooth wheels on a rail in 1813.

Oliver Evans said the time would come when we would start from Washington, breakfast in Baltimore, dine in Philadelphia, and sup at New York, and attain a speed of forty-five miles an hour, as fast as the "speed a bird flies." In 1824 the world was not ready for steam on railroads. In 1825 they laughed at the proposition of traveling fifteen miles an hour. They insisted that the trains be slowed down so as not to interfere with the stage coaches, and so destroy an active industry. From that time to the present, what has been done? Our continent is crossed from ocean to ocean by this iron rail, and the railroads of the present represent a vast accumulation of concrete thought. They may, in the gambling saloons of Wall street, represent only stock value, and there are people who think of

them only as of the amount of money they represent in the stock gambling. To those who are assembled here, in the Franklin Institute to hear a lecture on Mechanics, the railroads are the embodiment of thought, of mental effort almost too great for mind to grasp. See the Pennsylvania Railroad we are all so proud of, and the engines that eliminate space in speeding such rich freight across the continent we may say, from the Atlantic to the Pacific. As the railroad was in 1824 as compared to the railroad in 1883, so were the intellectual needs of the mechanics compared to his requirements to-day. When the Franklin Institute was founded it was intended that it should be a school for the mechanic, who desired instruction which could not be obtained in the public schools. Every effort was made to impart the instruction needed in the best and surest manner—lectures and special schools did this.

The Mechanical Engineer, must not only be a physicist in the broadest sense of the word, but there is scarcely any limit to the knowledge he must bring to his use, sooner or later, in his life work. Some one says that the engineer must understand matter and apply common sense to its use, to this add a clear knowledge of the laws that govern matter in motion. The early course of lectures, before the Franklin Institute were of an elementary character. They were the best for the purpose and could not be obtained at any other school. What has been the result of the work of the Institute? Gradually our people have begun to recognize the need of giving industrial education given in the public schools. You must bear in mind the High School of Philadelphia is the direct outgrowth of the Franklin Institute. At the present time it should be possible for the elementary information, formerly given only by the Institute, to be obtained free in the public schools. At the same time, there is reason why our lectures should still be delivered.

The class of lectures that may now do the most good are, perhaps, not elementary or primary in character. Lectures must entertain and instruct and suggest lines of thought and inquiry. In laying out the present course, several important elements have been considered; in the first place, many believe it is possible to have taught in the public schools the underlying principles of manual labor. I do most certainly think the use of tools, so needful in the trades, can be taught without teaching any trades. The use of tools may be very judiciously introduced in the course of study.

In the early history of our country the work-shops were not very far removed from the schools. It was almost impossible for a young man to attend school from one year's end to another. He had to work in the shops, on the farm, and attend school but part of the time and what was the result of such training? Good solid men live yet to attest its merit. What is the result of the later system of training of the public schools? The students are separated entirely from manual labor and their heads only trained, they get what makes them traders, doctors, lawyers; certainly not mechanics. Little is given to the students of the public schools below the high school, that will enable them to enter the work-shops, with the ready means of applying their school knowledge to practice. There is a very simple reason for this; the teachers are not mechanics; they are not expected to be; the scholars can more easily learn those things that relate to buying and selling than what relates to mechanical arts. It may seem very easy to apply the methods and rules learned at school to the practice of the machine shops; but you must bear in mind the instruction given in the public schools is only on the plane of the teacher or the writers of the books used in the schools. Teachers in the public schools should understand the principles of mechanics. The same rule of three, illustrated by examples pertaining to trade, is used by the mechanic in determining the speed of machines and calculating the size of pulleys to drive the machines—but the boy is not given examples in the direction of mechanics.

The examples prepared for the scholars have little or no reference to the uses of the mechanic. In the limited time of a lecture, it is impossible to present the full argument in favor of handicraft instruction. I have said some of the mechanical operations may advantageously be taught in the schools. A rest from the head-labor and the education of the hands will make the brain stronger; as an experiment in the direction of teaching the use of tools without teaching trades, Mr. Joshua Rose has been selected to deliver a course, beginning on the 16th of November. Mr. Rose is a very skillful English machinist who came to this country some years ago and has of late been writing many interesting papers in the scientific journals on mechanical manipulation; he does know how to use these tools.

Immediately after Mr. Rose has finished his course, Prof. A. J. Parker will deliver a course of lectures on Vital Dynamics, or the Laws of Mechanics, as applied to walking, running and swimming.

Great interest centres in what relates to the human frame, the animal frame and the laws that govern their motion, and modern science has thrown much light upon this subject.

It has been thought best to bring some of the interesting novelties in mechanic arts before the Institute in the lecture course. One branch of the mechanical arts, boiler-making, has in England and the Continent received a great deal of attention by engineers. Hydraulic power has taken the place of manual power and the riveting of boilers and ship plates is largely done by machinery in place of hand work. In order to have this brought before the Franklin Institute we have asked Mr. James Platt, who is familiar with the subject and is now visiting this country, to give a lecture which will be delivered on the fourth Wednesday of this month. Later, Mr. Henry R. Towne, of Stamford, Conn., son of the late Mr. John H. Towne, the founder of the Towne Scientific School of the University of Pennsylvania, will deliver a lecture on Crane Construction. The reason for this subject being selected is, that what tends to aid the ready handling of merchandise and heavy weights, as in the terminal facilities of railroads, merits careful attention. It was thought advisable to request of him this lecture so as to present the latest development of that industry in America, and as suggestive of the more extended use of power cranes.

Two lectures will be given by Mr. George M. Bond, of Hartford, Conn. He is connected with the well-known Pratt & Whitney Company, and has charge of some novel measuring machinery perfected by them. There was a time when the two-foot rule, rudely made, answered the mechanic's purposes. There is a saying in Germany that every hair in a carpenter's head is one-eighth of an inch in diameter; meaning, that a carpenter does not require closer measurements than one-eighth of an inch, not nearly so fine measurements as a machinist does, because he fits the joints to plan. The terms "full" or a "little full scant" indicated variations from exact size, but a little while ago; a vast change in regard to accuracy of measurement has now come over the whole mechanical industry. Now there is an attempt with almost all machinists to make machinery interchangeable in its parts. One branch, however, may need only coarse measurements while others need the most minute measurements and accuracy. The ordinary two-foot rule may answer for many purposes and be very convenient, but its use is limited. We have little devices

given to us for use in the work-shop which give a ready measurement as fine as the one-thousandth part of an inch, (showing one of the screw caliper gauges made by the Victor Manufacturing Company.) This gauge is graduated, each division representing the one-thousandth part of an inch. Any substance placed between the two points of contact in this gauge, and the gauge closed upon it, can be measured to the one-thousandth part of an inch. (Then showing a somewhat similar instrument made by Heilmann, Ducommunn and Steinlen, at Mulhouse, Germany.) Here is an instrument made, not purposely to measure, but rather to show the perfection which certain machine tools have reached in doing certain kinds of work. It holds between the contact pieces five cubes, each one being twenty millimetres square; these cubes have not been touched by the hand of a workman with a file; they are machine made to size only. Five of these cubes placed in a row measure one hundred millimetres in length. The screw in this instrument is one of the few examples in the country of a screw cut to the millimetre pitch. The circumference of the collar which surrounds the screw is divided into one-hundred parts, while in the case of the American instrument, you read to the one-thousandth part of an inch, here you read to the one-hundredth part of a millimetre, say to about $\frac{1}{2500}$ of an inch.

Mr. Bond is connected with an establishment making gauges of various kinds, and they have perfected a machine, the Rogers and Bond Comparator, which reads sizes more closely and which can compare sizes more closely than anything heretofore proposed. He will deliver a second lecture on Standards of Length as applied to Gauge Dimensions.

For one night the subject is yet unannounced, this it is expected will be well selected. These are the lectures which are to form the Course on Mechanics.*

As to the utility of lectures, as compared with books on the same subject, I desire to say a few words. When I speak to you in the lecture room, if you do not hear or do not understand, or if I make a verbal mistake, the result is you draw wrong conclusions. If I sit down and deliberately write my thoughts and publish them for you to read at your leisure, you will receive your information better and

* The unannounced lecture was delivered by Mr. Coleman Sellers, Jr., February 8; the subject being Mechanical Drawing—Free-hand drawing as applied to mechanics was illustrated.

more thoroughly than in a lecture room; so thinking men prefer to read lectures, not to hear them.

The lecturer fails in as much as he may make mistakes in his lecture—mistakes in words. The hearers may misunderstand him, their attention may be distracted by something else going on in the room, and when they bring their thoughts back again to the lecturer they may have forgotten a good part what preceded and it cannot be recalled. I once listened to a lecture on the Spectroscope, one of the best lectures I ever heard. The lecturer, a most able scientist, described in the introduction to his lecture a simple form of spectroscope, telling how two cheap spy glasses combined with a simply formed prism could be united to form an effective working spectroscope. Then he showed more perfect instruments of the kind, explaining how they were used. Finally he told of what wonderful discoveries made by means of the spectroscope, winding up with the assertion that by means of this simple instrument we are enabled to reach out towards the stars of the heavens and, grasping them with the hands of science, to analyze them as readily as we can the sands gathered on our seashore.

The lecturer satisfied me as he did many more who heard him, but a very bright and skilled machinist came to me the next day to ask how to make a spectroscope—explaining that his interest in the instrument was excited only when he learned what it would do—and, as this knowledge came after the description of it, he could not recall what had been uninteresting in the beginning. Had the lecturer told what the spectroscope enabled us to do and shown how it was used, and afterwards told how it could so easily be made, a better result would have followed so far as the teaching power of the lecture is concerned. The same lecture, however, published would be in proper sequence as delivered for, in a book, one can go over and over again the points needing most thought or refer back for what has escaped attention at the first reading.

It is possible at the present time, with the abundance of books at our command, for all who desire to study the mechanic arts, to do so better from books than from words spoken in the lecture room. I have here a book I advise all young men to purchase or to get from the library and read—"Experimental Mechanics," by Prof. Ball, is the title of it. Those lectures were delivered in Ireland and are models of clearness. The pictures in this book take the place of experiment.

The excuse for scientific lectures is that we are able to show experi-

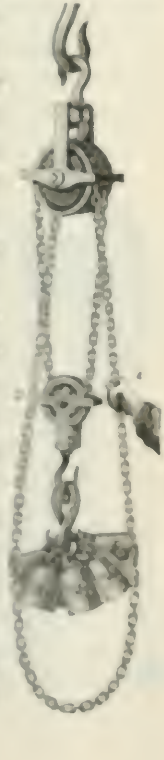
ments and enable people to see what cannot be understood in descriptions. Good illustrations go a long way towards making the book better than the lecture. A single sketch will tell me a great deal more than many pages of printed matter will do. In this work of Prof. Ball's, the student is carried through many of the laws that are necessary for the mechanic to understand, that he must understand, that are absolutely necessary for him to really know.

Prof. Ball, during this course of lectures, delivered one full of interest on what is known as Weston's Differential Pulley Block or Hoist. I have one of them here this evening and, while I cannot devote to its explanation as much time as Prof. Ball did, I want to make it useful as an illustration of the care that must be exercised in drawing conclusion from experiment. A strong point in Prof. Ball's course of lectures is the clear and precise manner in which he explains the subject he has under consideration, and the lecture on the Differential Pulley Block is a fitting sequel to those preceding it, which carried the student step by step through the laws of mechanics that must be known to enable one to fully understand the operation of this simple machine for hoisting.

I cannot go over the same ground, but I can in a few words explain what is meant by velocity ratio and its relation to power actually transmitted through or by a machine. Every boy learns early in life that if he wants to ride see-saw with a companion who weighs as much as he does, that a board balanced over a fence rail will be ready to take boys of equal weight on its ends, and that each will ride through an equal arc, or that each one will ride as high as the other. If, however, one boy is heavier than the other, he soon learns that the board must be readjusted to the conditions of weight, and that the heavy boy will not only be nearer the fence but will not rise so high as the one who is farther from the fence on the long end of the board. If one boy weighs just twice as much as the other, the distance of the heavy boy from the fence will be just half the distance that the lighter one is from the fence on the other side. In the see-saw ride the heavy boy will rise and fall just half the distance that the lighter one does, and he will travel through the air in rising and falling at just half the speed of the lighter one. The velocity ratio of the two will be as two is to one.

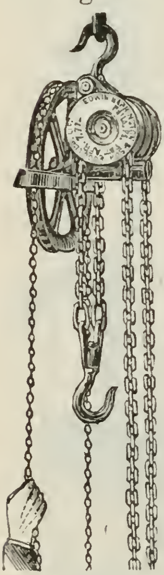
The governing law in this case covers all kinds of levers and all mechanical motions. If one part of a hoisting machine of any kind to which the power is applied travels through a distance which is

found to be a certain number of times the distance through which the load lifted travels in the same time, that number expresses the velocity ratio which holds in that case. If, in the case of an ordinary block and fall, the rope pulled to raise the weight requires say five feet to be overhauled to raise the weight one foot, then the velocity ratio is five to one. If it was not for friction, velocity ratio and power ratio would be the same. Thus, if it requires five feet of rope to be overhauled to raise a weight one foot, then one pound applied to the hoisting rope should raise the weight of five pounds; but it will not do it. The friction of the machine of the pulleys and the friction of the bending rope—the power it takes to bend the rope—these and other matters diminish the power obtained from any given force, and the theoretical power required to hoist the given load divided by the actual power comes to be called the efficiency of the machine. If, for example, in the case of the hoisting device of five to one velocity ratio, it is found that it requires two pounds passing through a space of five feet to raise five pounds one foot high, in place of one pound moving the same distance to do the same work, then while the velocity ratio is five to one the efficiency of the machine is only one-half, and fifty per cent. of the power has been lost in friction. Friction thus stands in our way, and in some cases it stands very much in the way. It stands right square in the way of all who try to make perpetual motion machines. Friction is not, however, always objectionable, it is in many cases the thing sought for. We seek to diminish friction by many means when we do not want it, we seek to increase it when it is an advantage to us. The locomotive, that thunders across the continent with its wealth of life or freight, bites the steel rail on which it travels with the teeth of friction. It is friction and only friction that holds it to the smooth rail. It may require ten tons to cause a fifty-ton engine to slip with its locked wheels on a smooth rail; if so, then the fifty-ton engine has nearly ten tons of power in its pull on the train that it hauls along the smooth rail of the road.



The Weston differential pulley block I now show you has a load on it of one hundred pounds and the velocity ratio of the machine is sixteen to one. That is

to say, to raise the load one foot I must overhaul sixteen feet of the loop which serves as a hoisting loop. I pull sixteen feet of chain over the sheaves to hoist the load one foot. If friction did not prevent I should hoist the load of 100 pounds with a force equal to one-sixteenth of the 100 pounds, that is, with six and one-quarter pounds, but I will now apply a spring-balance to the hoisting rope and measure in that manner the force that must be exerted to lift 100 pounds. I am now exerting a pull of 22 pounds and the load has not started, but when in motion it seems to require a pull of about twenty pounds to keep up the motion. If now we divide the theoretical power required to hoist by the actual power required, that is to say, if we divide 6·25 by 20 it will be seen that the efficiency of the machine is ·31 per cent. and there is therefore a loss in friction of 69 per cent. While this loss seems great it has its compensating advantages, for you will observe there is no tendency for the load to overhaul when I no longer pull on the hoisting chain; in point of fact, when I desire to lower the weight I must actually exert some power on the opposite loop of the chain to haul the load down. I do not exert very much force, it is true, to lower, but still the force is appreciable. Now we sum up the advantages of the machine thus: It is simple, not likely to get out of order, will not overhaul, but will hold any amount of weight consistent with the strength of the machine without any danger of the weight running down. Safety is one of its great advantages. These machines, made in this country, by the Yale & Towne Manufacturing Co., of Stamford, Conn., have come into very general use.



I will now take down the Weston differential pulley blocks and will hoist a load with a device made in this city by Messrs. Edwin Harrington & Son. In this machine the power to hoist is obtained by means of a worm or endless screw working into a worm wheel, and two sprocket wheels, one on each side of the worm wheel carry the chain to which the load is hung, which, while it forms a loop has no differential motion as in the Weston hoist, but each revolution of the worm wheel hoists the load through a space equal to the circumference of the sprocket wheels measured at the centre of the chain that passes over them. A separate small chain passing over a sprocket wheel on the shaft of the worm or endless screw

serves to operate the machine in hoisting. Thus if I pull on one side of this loop or endless chain I may with a motion of six feet raise the load one inch. I will not be particular as to the exact ratio. I have 35 pounds hanging on the chain hook, and you will observe that three pounds applied to the small chain barely hoists that load. Theoretically, based on the velocity ratio of the machine, less than one pound should have hoisted the load, and the efficiency of the machine is 27 per cent., the loss in friction being 73 per cent. It does not seem liable to run down with any load, and a given weight is hoisted with less effort than on the Weston machine because the velocity ratio is greater, but the load is hoisted slower.

This machine is simple, not likely to get out of order, works very smoothly, in fact more smoothly than the one we first tried, and will carry a load without any tendency to overhaul. In both cases, you must remember, there is more than 50 per cent. lost in friction. Prof. Ball concludes from experiments similar to those shown you this evening that the principle involved extends to other mechanical powers and may be stated generally, thus: "When rather more than half of the applied energy is uselessly consumed by friction, the load will remain suspended without overhauling." This general statement is clear and conclusive, and we are led to believe that in all hoisting machines if there is a loss of more than half of the applied energy in useless friction the machine can be depended on to hold the load without any tendency to overhaul.

Now follow me, please, in another simple experiment. I have had made for illustration this evening a crude hoisting machine involving a series of spur wheels gearing into one another in such a way that power applied to one end of the series will serve to hoist a load at the other end of the series. The velocity ratio is such that but for friction we might raise a load of five pounds with $\frac{8}{10}$ of one pound, but it requires two pounds to lift five pounds, so that the efficiency of the machine is 40 per cent., and the loss in friction is 60 per cent. In this case, with a loss of friction of more than 50 per cent., according to Prof. Ball's statement there should be no danger of allowing the load to hang on its hook without any applied power at the other end of the series. Now observe what when I take away the two pounds required to lift the load. You see the load overhauls fast enough, and what is more, the heavier the load the faster it will overhaul. In this case I have simply strung a series of wheels together until their multi-

plied axle friction is more than 50 per cent. in the whole. But as each pair of the series is capable of overhauling, the whole will overhaul with a load sufficient to overcome the friction of the machine. If this was not the case, and ordinary clock series of wheels could not be depended on to run, for it is the load applied to the drum of clock series and which has been wound up, running down operates the clock. Let us now for a moment think how Professor Ball has erred. His experiments warrant his assertion, and what he says is strictly true as regards all similar mechanical powers involving few parts. Had he said, in any mechanical pair, that is, machine consisting of two parts, if rather more than 50 per cent. of the applied energy is lost in useless friction then the machine will not overhaul. He has made a mistake in generalising from too few experiments. The converse of his rule is true as applied to any machine of the kind, viz.: If a hoisting machine is so constructed as not to overhaul, and the reason for its not overhauling is from loss of applied energy in needless friction, it is safe to infer that the total loss in friction is rather more than 50 per cent. Thus in the case of a screw working in a nut without either collar friction or end friction, like a step. We have an example of this familiar to you all in the screw and nut of the elevating music or piano stool. The load resting on the stool does not cause the screw to run down, friction alone prevents its so doing; it is safe to infer that the loss in friction is at least 50 per cent., and if you attempt to raise a load on the stool by screwing it up under the load, the force you apply to do so will be more than double what the velocity ratio would call for.

I do not use this error in Professor Ball's admirable lectures as an example, this evening, with any intention of speaking disparagingly of them, but to give you an idea of the care that must be exercised in drawing conclusions from our observation of facts, and at the same time show you how much more certain we can be about what we can read with care, than we ever can be about what we think we have heard a lecturer say.

(To be concluded.)

Encke's Comet.—Backlund finds that the empirical correction which is required to perfect the theory of Encke's comet, after being nearly constant for fifty years, experienced a considerable variation. The average acceleration of the mean movement, between 1871 and 1881, was only about half as great as the value found by Encke and Asten for the period from 1819 to 1865.—*Comptes Rendus.*, June 11, 1883.

INITIAL CONDENSATION OF STEAM CYLINDERS.

By William Dennis Marks,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

In previous papers published in this Journal it has not been assumed that the actual steam from boiler per horse-power per hour was other than directly proportional to the steam registered by the indicator.

It may be a constant fraction or it may be a different fraction for each point of the stroke at which steam is cut off.

We have as yet no experimental proof of what the ratio is that exists between the actual steam and the indicated steam.

It may be of service to call attention to hypotheses as to what this ratio may prove to be.

Let d = the diameter of the steam cylinder in feet.

Let s = the stroke plus clearance of the steam cylinder in feet.

Let V = the volume of the cylinder in cubic feet $= \frac{\pi d^2 s}{4}$.

Let e = the fraction of the volume of cylinder at which steam is cut off.

Let N = the number of strokes per minute.

Let T_b = the temperature of initial steam.

Let T_e = the temperature of exhaust steam.

We can then say that eV is the volume of steam existing as vapor in the cylinder at the instant of cut-off.

To this volume of steam as vapor must be added a large quantity which is condensed during the entrance of the steam *before expansion begins*. What happens to the steam during its expansion is a matter of comparatively small moment, since we know that the curve of pressures is quite as nearly an equilateral hyperbola, as any other curve within limitations which have been established quite independently of any assumptions regarding the ratio between actual and indicated steam. (See this Journal, December, 1883.)

Statements as to the enormous amount of initial condensation seem almost incredible, and yet it is difficult to account for the great discrepancy which does exist in many cases on any other hypothesis.

In nearly every set of experiments made upon the steam engine there has been some missing link in the chain of evidence, and as a

result the statements made cannot be proved, nor have the doubters been able to disprove them.

If we make the assumption that the initial condensation is proportional to the surface presented up to the moment of cut-off, we have

$$\text{Area of piston and cylinder-head} = \frac{\pi d^2}{2}.$$

$$\text{Area of cylinder walls} = \pi des.$$

$$\text{Their sum} = \pi d \left(\frac{d}{2} + es\right). \tag{1}$$

If we assume that the condensation is also proportional to the difference in temperature of initial and exhaust steam, we have

$$(T_b - T_e) \tag{2}$$

If further we assume that the condensation is proportional to the time of exposure, we have

$$\frac{1}{N} \text{ minutes} \tag{3}$$

for the time of exposure of the cylinder to exhaust steam, and

$$\frac{e}{N} \text{ minutes,} \tag{4}$$

for the time of exposure of the walls to initial steam.

Since the exposure of the exhaust is much longer than that of the initial steam, we can assume as the more tenable hypothesis that the cylinder walls already let down in temperature by a low terminal pressure, lose heat to a depth proportional to $\frac{1}{N}$.

The great pressure and high temperature of initial steam will then in all probability cause so much more rapid condensation of initial steam as to render its lesser time of exposure comparatively unimportant.

The weight of steam indicated each stroke is

$$\frac{62\tfrac{1}{2}\, eV}{S} = W \tag{5}$$

in which S is the specific volume for the pressure at cut off. If now we assume the actual steam from boiler used in one stroke to be pro-

portional to difference of temperatures, area exposed, and time of exposure of initial steam, plus vapor; we have for steam from boiler

$$W_a = 62{\cdot}5\,\frac{cV}{S} + \left[\left(T_b - T_e\right)\pi d\left(cs + \frac{d}{4}\right)\frac{c}{N}\right]C \qquad (6)$$

If we assume $c = \frac{1}{2}$ or less $\frac{d}{2}$ becomes $\frac{d}{4}$, or less, in which C represents the weight of steam condensed by a difference of one degree Fahrenheit in an iron surface of one foot area exposed for one minute.

If, as seems more probable, we assume that the condensation is proportional to the time of exhaust, we have

$$W_a = 62\tfrac{1}{2}\,\frac{cV}{S} + \left[\left(T_b - T_e\right)\pi d\left(cs + \frac{d}{2}\right)\frac{1}{N}\right]C. \qquad (7)$$

If we let $r = \frac{W_a}{W}$, we then have from eq. (7)

$$r = 1 + \frac{S(T_b - T_e)}{62\tfrac{1}{2}\,N}\,C\left[\frac{4}{d} + \frac{2}{cs}\right]. \qquad (8)$$

The reason for giving the preference to formula (7) is that the depth of cooling is probably more influenced by the time of exposure of the exhaust, and that the condensation of initial steam would seem to be instantaneous.

The order of events would seem to be as follows, the engine having attained its regular speed, and the cylinder an average heat.

The entering steam touching the interior of the cylinder condenses instantaneously and warms it up to a temperature of the steam, this warmth proceeds to a depth proportional to the depth already cooled by the exhaust, the steam then expands after cut-off, falling in temperature and losing heat, first by warming up the cooled cylinder walls, second in doing work, however the heated iron of that part of the cylinder exposed before cut-off, gives up heat and vaporizes the condensed water of initial condensation in the attempt to equalize the temperatures throughout the cylinder, which is effected by a transfer of condensation following the motion of the piston-head.

At the end of the stroke the temperature of the whole internal surface and of the steam is that of the terminal pressure, the steam having really expanded with fresh accessions of heat and of vapor from that part of the cylinder exposed to initial steam; that is, exposed before the cut-off occurs.

Next in the order of events the exhaust opens and the whole interior of the cylinder is exposed to the temperature of the exhaust, the piston and cylinder-head being exposed on an average twice as long as the cylinder walls.

In every engine these changes, whatever they may be, establish an equilibrium among themselves, and the result is that a certain uniform quantity of heat is lost each stroke, provided the thermal value of the steam does not vary.

What is said is merely advanced as a hypothesis, which so far as regards the expansion, receives a probable verification from the curves of the indicator, which approximate to the equilateral hyperbola, more and more nearly as we improve the performance of engines. Dropping the discussion of what befalls steam after the point of cut-off is reached, let us return to initial condensation.

From Mr. Hill's experiments we take the following data:

HARRIS-CORLISS ENGINE.

	Condensing.	Non-condensing.
(1) Stroke s	4·08 ft.	4·08 feet.
(2) Diameter d	1½ ft.	1½ feet.
(3) Volume cylinder V	7·291 c. ft.	7·291 c. ft. Calculated.
(4) True point of cut-off	0·1355	·1491.
(5) Steam from boiler W_a	32063·19 lbs.	32160·25 lbs. In 10 hours.
(6) Its thermal value U	1315·86 B. U.	1255·74 B. U. Experimental.
(7) Thermal value of saturated steam	1214·88 B. U.	1214·74 B. U. From Porter's tables.
(8) For the pressure P_b	90·07 lbs	89·52 lbs. By steam gauge.
(9) Temperature steam T_b	532·8 deg. F	532·4 deg. F. Calculated and table.
(10) Temperature exhaust T_e	145·4 deg. F	212·6 deg. F. Calculated and table.
(11) Specific volume S	257·	258· For initial pressure.
(12) Number of strokes N	151·66	151·62
(13) Pressure at cut-off P_c	86·97	85·91 lbs. By steam gauge.
(14) Specific volume at cut-off	264·	266·5
(15) Steam by diagram W	19335·94 lbs.	20625· lbs. Calculated for point of cut-off, less comp. steam.
(16) Mean eff. pressure P	35·67 lbs.	28·94 lbs.
(17) Max. compression (abs.) B_m	41·07 lbs.	60·57 lbs.
(18) Barometric pres. (abs.)	14·47 lbs.	14·47 lbs.
(19) Ind. horse-power (HP)	165·58	134·29
(20) Clearance k	0·0189	0·0189

(15) is calculated from the following formula:

$$\text{Water in 10 hrs.} = 10\,\frac{\left(c - k\,\frac{B_m}{P_c}\right)}{PS} \times \text{H}^{\text{P}} \times 859375. \qquad (9)$$

$$\text{Condensing } 10 \times 165{\cdot}58\,\frac{{\cdot}1355 - {\cdot}0076}{35{\cdot}67 \times 264} \times 859375 = 19335{\cdot}94 \text{ lbs.}$$

$$\text{Non-condensing } 10 \times 134{\cdot}29\,\frac{{\cdot}1491 - {\cdot}0113}{28{\cdot}94 \times 266{\cdot}5} \times 859375 = 20625 \text{ lbs.}$$

The temperature of the steam is computed from its thermal value. It is much to be regretted that this temperature was not directly observed.

The formula used is

Degrees of superheating = (Observed thermal — Saturated thermal value) × 2 (10)

which when added to the temperature observed by Regnault for saturated steam gives the temperature of the initial steam.

The specific heat being assumed at ·5 with Hirn, rather than ·48 as given for steam by Porter from Regnault.

Comparing the results as to weights of steam.

For Harris-Corliss engine, condensing.

Actual steam from boiler	32063·19
Computed steam at cut-off, less amount of comp.	19335·94
Computed steam at terminal pressure, less amount of comp.	22775·81

giving $r = 1{\cdot}657$ for point of cut-off.

For same engine non-condensing.

Actual steam from boiler	32160·25
Computed steam at cut-off, less amount saved by comp.	20625·00
Computed steam at terminal pressure less comp.	24190·78

giving $r = 1{\cdot}559$ for point of cut-off.

Substituting in formula 8 we have for condensing trial

$${\cdot}657 = \frac{264(387{\cdot}4)}{62\tfrac{1}{2} \times 151{\cdot}66}\,C[2{\cdot}667 + 3{\cdot}617]$$

$$C = 0{\cdot}00969 \text{ lbs.}$$

For non-condensing trial

$${\cdot}559 = \frac{266.5 \times 319{\cdot}8}{62\tfrac{1}{2} \times 151{\cdot}62}\,C[2{\cdot}667 + 3{\cdot}289]$$

$$C = 0{\cdot}01044 \text{ lbs.}$$

Difference = 0·00075 lbs.

That is, we might infer from the above induction that the condensation of a plate of cast iron one foot square rapidly subjected to varying temperatures is about $\frac{1}{100}$ of a pound per minute and per degree Fahrenheit. It must not be forgotten that our premises are not very accurate.

Having thus determined a value of $C = \frac{1}{100}$ lbs., we can discuss the point of cut-off.

Actual steam $= r$ times indicated steam. For one stroke

$$\frac{\text{Work}}{\text{Cost of work in steam}} = y = \frac{PV}{r\,\frac{62\frac{1}{2}}{S}\,eV} \tag{11}$$

Clearance and compression being neglected.

Substituting the value of r from equation (8) we would have

$$y = \frac{P}{\frac{62\frac{1}{2}}{S}\,e + \frac{T_b - T_e}{100\,N}\left[\frac{4e}{d} + \frac{2}{s}\right]} \tag{12}$$

and letting

$$A = \frac{62\frac{1}{2}}{S} \tag{13}$$

$$D = \frac{T_b - T_e}{100\,N} \tag{14}$$

We have for a maximum value of equation (12).

$$e = \frac{B}{P_b} + \frac{2Dd}{s(Ad + 4D)}\ \text{nat. log.}\ \frac{1}{e} \tag{15}$$

If in this we substitute the values for the Harris-Corliss Engine condensing we obtain

$$A = \frac{62{\cdot}5}{257} = 0{\cdot}243 \qquad D = \frac{387{\cdot}4}{100 \times 150} = {\cdot}0258$$

$$e = \frac{3{\cdot}35}{104{\cdot}55} + \frac{2 \times {\cdot}0258 \times 1{\cdot}5}{4({\cdot}243 \times 1{\cdot}5 + 4 \times {\cdot}0258)}\ \text{nat. log.}\ \frac{1}{e}$$

$$e = {\cdot}032 + {\cdot}0414\ \text{nat. log.}\ \frac{1}{e}$$

If in this equation of condition we assume $e = \frac{1}{8} = 0{\cdot}125$ for a first trial we have $\cdot125 = 0{\cdot}032 + {\cdot}0858 = 0{\cdot}118$.

Assume $e = \frac{1}{9} = {\cdot}111$ for a second trial we have

$${\cdot}111 = 0{\cdot}032 + {\cdot}0906 = 0{\cdot}122.$$

We see, therefore, that the Harris-Corliss engine condensing might have cut off at about $\frac{1}{8}$ or a little over, but not as high as [illegible], with the greatest actual economy of steam per *indicated* horse-power. It was possibly doing its best per net horse-power clear of the engine friction as it was run (0·1355 cut-off.)

These limitations are also derived by other methods in this JOURNAL, August, 1880, and December, 1883; also in "The Relative Proportions of the Steam Engine," Chap. xvi., at somewhat greater length than elsewhere.

If now we take up the same engine non-condensing we have

$$A = 0{\cdot}243 \text{ and } D = \frac{319{\cdot}8}{100 \times 150} = {\cdot}0213$$

$$e = \frac{14{\cdot}89}{104.} + {\cdot}081 \text{ com. log. } \frac{1}{e}$$

$$e = 0{\cdot}143 + {\cdot}081 \text{ com. log. } \frac{1}{e}$$

If in this equation of condition we assume

$$e = \tfrac{1}{5} = {\cdot}20 \text{ we have } {\cdot}20 = {\cdot}143 + {\cdot}057 = {\cdot}20.$$

That is to say, the Harris-Corliss engine non-condensing was probably run so as not to produce its best actual economy of steam as its cut-off was ·15 of the volume and therefore too early, not for economy of indicated steam, but for economy of actual steam from boiler.

A laborious calculation of the amount of steam re-evaporated in the steam cylinders at various points from the point of cut off to exhaust opening has led the writer to believe that Mr. Hill's surmise as to excessive leakage in the case of this engine is incorrect, when the engine was in motion and thoroughly warmed up.

The large percentage of initial steam condensed in the case of the non-condensing trial was caused, perhaps, by a too early cut-off. The Harris-Corliss engine has been selected because the diagrams given for that engine would appear to show least probability of a leak past the piston and because Mr. Hill remarks, "Mr. Ellis, of the Harris engine attempted to hasten the seating of the steam valves of his engine by filing previous to the trials with good results as shown by the diagrams. No effort was made with either the Reynolds or Wheelock engines to seat the valves except by wear."

Taking the case of a pair of diagrams from Buckeye engine with Korting Jet Condenser, we have the following data:

Stroke, $s = 44$ inches $= 3{\cdot}667$ feet.
Clearance, $k = {\cdot}02s = {\cdot}07334$ feet.
Diameter, $d = 22$ inches $= 1{\cdot}833$ feet.
Abs. initial pressure, $P_b = 92{\cdot}7$ pounds per square inch.
Abs. back pressure, $B = 4{\cdot}7$ pounds per square inch.
Number of strokes, $N = 140$ per minute.
Temperature of initial steam, $T_b = 322{\cdot}14$ deg. Fahr.
Temperature of exhaust steam, $T_e = 159{\cdot}55$ deg. Fahr.
Specific volume, initial steam, $S = 286{\cdot}9$.

$$D = \frac{T_b - T_e}{100N} = \frac{162{\cdot}59}{14000} = 0{\cdot}0116 \qquad A = \frac{62\frac{1}{2}}{S} = \frac{62{\cdot}5}{287} = 0{\cdot}218$$

$$e = \frac{4{\cdot}7}{92{\cdot}7} + \frac{2 \times {\cdot}0116 \times 1{\cdot}833 \times 2{\cdot}3026}{3{\cdot}667[0{\cdot}218 \times 1{\cdot}833 + 4 \times {\cdot}0116]} \text{ com. log. } \frac{1}{e}$$

$$e = {\cdot}0507 + 0{\cdot}060 \text{ com. log. } \frac{1}{e}$$

In this equation of condition assume $e = \frac{1}{8} = {\cdot}125$.
We have

$$0{\cdot}125 = {\cdot}0507 + {\cdot}054 = {\cdot}105.$$

$$\text{For } e = \tfrac{1}{9}\ 0{\cdot}111 = {\cdot}0507 + {\cdot}0572 = {\cdot}108.$$

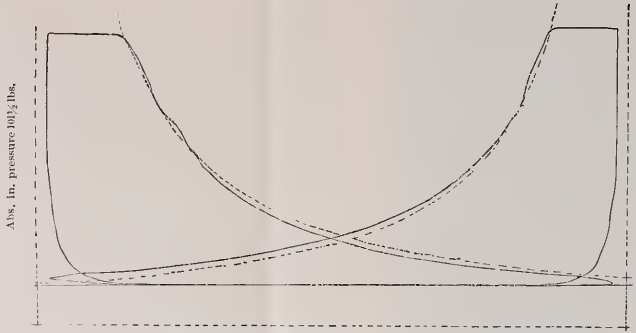
That is, it would appear as if the greatest actual economy per indicated horse-power would have been reached assuming the steam to be saturated and neglecting the clearance and compression with a cut-off of nearly $\frac{1}{10}$ the volume. The actual cut-off of the diagram would appear to be very closely $\frac{1}{8}$ of the cylinder volume.

All engineers are agreed upon the point that the presence of clearance causes loss.

Compression, too, must cause some small loss of efficiency of steam, as well as a loss of power in the engine.

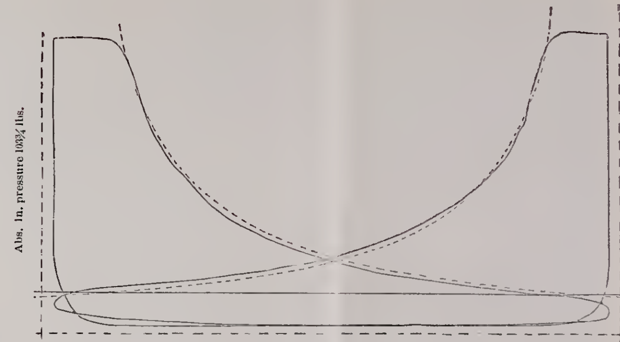
However, we cannot avoid clearance entirely, it being doubtful if mechanical considerations will permit us to get much below the 2 per cent. clearance already attained, and therefore we must correct the one evil by the other so far as possible.

Does it not seem possible, too, since the specific heat of steam under constant pressure is but one-half that of water, that superheating steam will not diminish initial condensation directly in proportion to the

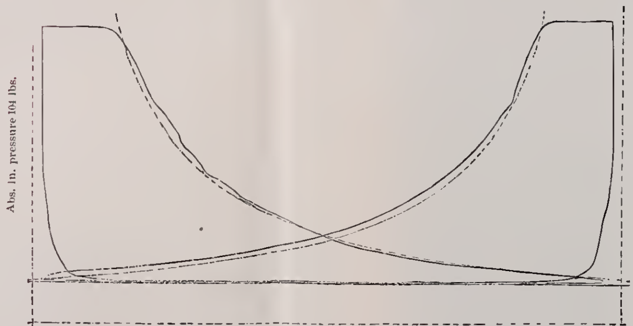


NON-CONDENSING HARRIS-CORLISS, NO. 28, JUNE 22D, 11.15 A. M.—THOMPSON INDICATOR.

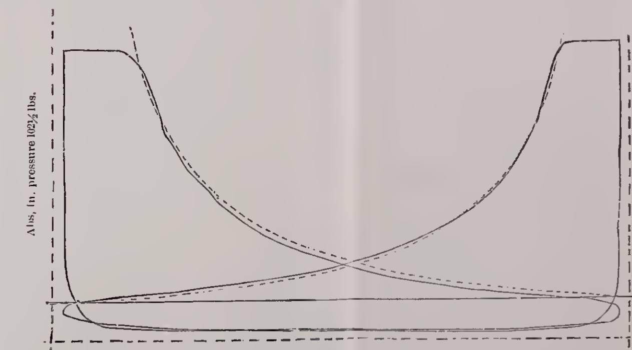
The broken curve is an equilateral hyperbola from the point of cut off in each case of Harris-Corliss Engine.



CONDENSING HARRIS-CORLISS, NO. 27, JUNE 21ST, 11.45 P. M.



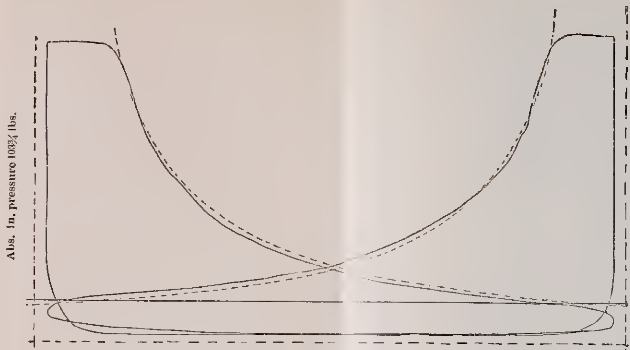
NON-CONDENSING HARRIS-CORLISS, NO. 14, JUNE 22D, 7.45 A. M.



CONDENSING HARRIS-CORLISS, NO. 34, JUNE 22D, 1.30 A. M.

The above diagrams of the Harris-Corliss Engine are photo-engraved reproductions from Mr. Hill's diagrams, and are as nearly fac-similes of the originals as possible. However, as the errors of reproduction ar given with each diagram as a scale.

The diagrams of the Buckeye Engine and the Brown Engine have been engraved from templates carefully made for Mr. Thompson from the original diagrams, and may be relied upon as being practically acc



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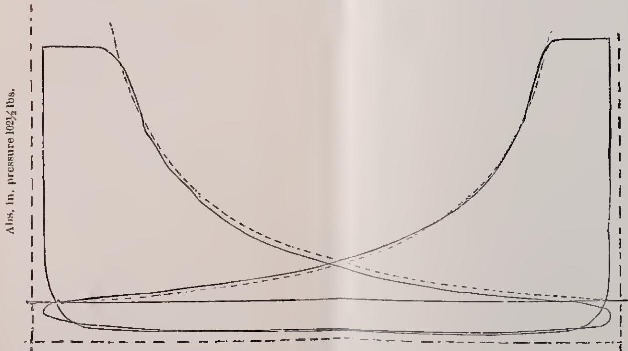

CONDENSING HARRIS-CORLISS, NO. 34, JUNE 22D, 1.30 A. M.

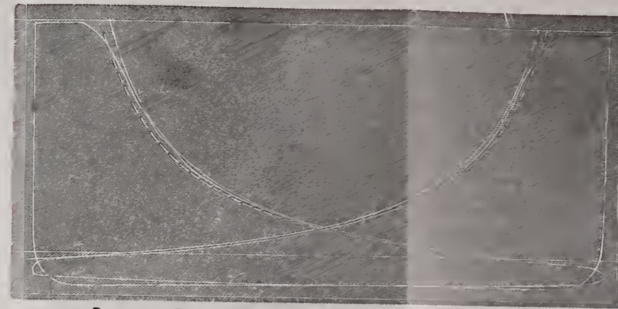

DIAGRAM OF BUCKEYE AUTOMATIC ENGINE. KORTING JET CONDENSER.
The solid curve above is the Adiabatic Curve, and the broken curve below is the Isothermal Expansion Curve, traced on the diagram for comparison, and beginning at the toe of the diagram.
SCALE, 40 lbs.

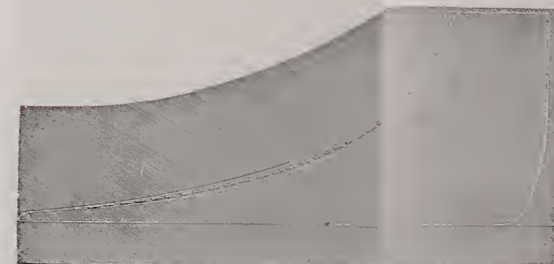

DIAGRAM OF THE BROWN ENGINE. NON-CONDENSING. TAKEN BY F. W. BACON.
SCALE, 40 lbs.

Mr. Hill's diagrams, and are as nearly fac-similes of the originals as possible. However, as the errors of reproduction are in proportion, the diagrams can be reworked by using the ABSOLUTE INITIAL PRESSURE emplates carefully made for Mr. Thompson from the original diagrams, and may be relied upon as being practically accurate.

number of degrees of superheating, but rather in proportion to half the degrees of superheating? In other words, is it not more probable that T_b should be made equal to the temperature of saturated steam of the given pressure plus the number of British units by which its thermal value is less than that of the superheated steam under consideration? If we consider the properties of iron alone, is it not possible that superheating may increase the amounts of initial condensation?

The fact of initial condensation in large quantity must influence subsequent expansion, because we have not only a surface of hot iron, hotter than the steam the moment it begins to expand, but also on this surface a film of water ready to vaporize the instant the pressure upon it is relieved, and thus to augment the volume of the expanding steam. When steam is not dry as taken from the boiler, it is easy to see that the volume and pressure of the steam may be so much augmented as to raise the expansion line above a true hyperbola.

The temperature of the steam and cylinder surface falls during expansion, but still a film of water at this lower temperature remains upon it, and instantly at the opening of the exhaust vaporizes, drawing its heat from the cylinder's surface, cooling the piston and cylinder head to the greatest depth, because they are the longest exposed, the result being increased initial condensation, and making the time of exposure to exhaust $\frac{1}{N}$ the controlling element rather than the time of exposure to initial steam $\frac{e}{N}$.

If in equation (8) we substitute the value of T_b under the above assumption we have

For the Harris Corliss engine condensing	$C = 0{\cdot}01306$
" " non-condensing	$C = 0{\cdot}01518$
Difference....................................	$0{\cdot}00212$

It would not appear from this that these assumptions are as correct as the preceding, which give results differing by 0·00075 pounds of steam per minute per square foot of surface raised one degree Fahr.

It is worthy of note that the superheated steam in the Harris Corliss engine must have instantly become very wet steam upon its admission to the cylinder, and therefore if damage is done by superheated steam, its evil effects will appear upon the valve motion and upon lubricants fed through the steam pipe.

It would seem as if especial care given to the jacketing of the cylinder barrel would be useless trouble until we have suppressed initial condensation *due mainly to the piston and cylinder heads.*

Even were we to obtain very good non-conducting surfaces for these latter parts, it is doubtful if a film of water would not appear on them and demand conversion into steam at the beginning of each stroke.

Taking next the case of a Brown engine, non-condensing, steam-jacketed, data as follows:

Stroke, $s = 42$ inches $= 3{\cdot}5$ feet.
Clearance, $= {\cdot}02s = {\cdot}07$ feet.
Diameter, $d = 16$ inches $= 1{\cdot}333$ feet.
Abs. initial pressure, $P_b = 88{\cdot}7$ pounds per square inch.
Abs. back pressure, $B = 18$ pounds per square inch.
Number of strokes, $N = 120$ per minute.
Temperature of initial steam, $T_b = 319{\cdot}01$ deg. Fahr.
Temperature of exhaust steam, $T_e = 222{\cdot}38$ deg. Fahr.
Specific volume of steam, $S = 301{\cdot}02$.

Steam wet. Substituting in formulæ (13), (14) and (15)

$$D = \frac{96{\cdot}63}{12{,}000} = {\cdot}00805 \qquad A = \frac{62{\cdot}5}{301{\cdot}02} = 0{\cdot}207$$

$$e = \frac{18}{88{\cdot}7} + \frac{2 \times {\cdot}00805 \times 1{\cdot}333 \times 2{\cdot}3026}{3{\cdot}5\,[{\cdot}207 \times 1{\cdot}333 + 4 \times {\cdot}00805]} \text{ com. log. } \frac{1}{e}$$

$$e = 0{\cdot}203 + {\cdot}046 \text{ com. log. } \frac{1}{e}.$$

Assume $e = \frac{1}{4} = {\cdot}25 = {\cdot}203 + {\cdot}027 = {\cdot}23$, or very nearly the same as assumed.

In the diagram the steam would seem to be cut off at about $\frac{1}{5}$ of the cylinder volume.

It would seem, when we use superheated steam, as if the condensation on the interior of the cylinder should be less than when saturated steam is used, but this is dependent upon the action of the steam.

If the steam condenses only as it comes in contact with the walls, that is, condenses as a piece of ice melts, on the outside, the main body of the steam *will remain superheated,* and successive layers of steam on the outside be condensed until the walls are of the same temperature as its temperature of saturation, after which the superheated steam would strive to re-evaporate the condensation, and the iron to keep it condensed and add more to it, with all the advantage on the side of the iron. Since, if we assume steam of an average specific volume of

300, their comparative weights, volume for volume, are—iron 2,160, steam 1, and as the specific heat of steam is 0·48 and that of iron 0·12, we see that, volume for volume or layer for layer, iron will take 540 times as much heat as steam. So we see the iron will not only keep what it has condensed, but will add more to it by conducting the heat from the film of water upon it away so rapidly as to cause additional condensation in the adjacent layers of steam, which have comparatively no conducting power at all, if we can draw any inference from the ease with which priming occurs in it, and the suspension of globules of water during expansion of steam.

The advantages of superheated steam will be found to be in the more complete re-evaporation during expansion leaving a drier cylinder and consequently less to be evaporated by the heat of the cylinder during the exhaust, which will therefore be cooled to a lesser depth.

It is not surmised that the temperature of the iron of the steam cylinder rises above the temperature of saturated steam of the initial pressure, but the probability is suggested that the iron gets more heat in proportion to the superheating, and therefore re-evaporates the steam more readily and thoroughly. Certainly it would not appear, in the case of the Harris-Corliss engine condensing, that 66 per cent. of the indicated steam should be condensed at cut-off, or with the same engine non-condensing 56 per cent. of the indicated steam should have been condensed at cut-off, if all the superheating of the initial steam had vanished before condensation began.

Neither does it appear from the diagrams that the superheating had the effect of raising the expansion curve above an equilateral hyperbola in the Harris engine, nor does wet steam seem greatly to modify the expansion curve of the Brown engine.

It does not seem probable, however, that an engine using super-heated steam, as did the Harris, should most economically cut off later than the Buckeye engine, assumed to use saturated steam, yet this would appear to be the case from the formulæ used and may really be the case, because of the greater specific volume of superheated steam. It has already been shown that even if all the steam used appeared in the diagram no great economy would result from a cut-off earlier than ⅛ stroke.

The fact, however, is undeniable that the amount of heat conducted away is proportional to the conductivity and heat capacity of the iron cylinder, and we are told that this conductivity is directly proportional to the difference of temperatures.

(To be concluded.)

AN INVESTIGATION LOCATING THE STRONGEST OF THE BRONZES.

By W. Ernest H. Jobbins, M. E.

(Continued from page 103.)

The research was now restricted to the examination of alloys lying nearer the point copper = 100, *i. e.*, the upper vertex of the triangle, as seen in the figure, and all such alloys were tested by tension, compression, torsion and transverse stress. The results are quite accordant, and the quality of the metal could be judged as well by one set of data as another, although, as a matter of course, the strain-diagram, obtained automatically, gave the best idea of the nature of the metal where the observer had been accustomed to that method of

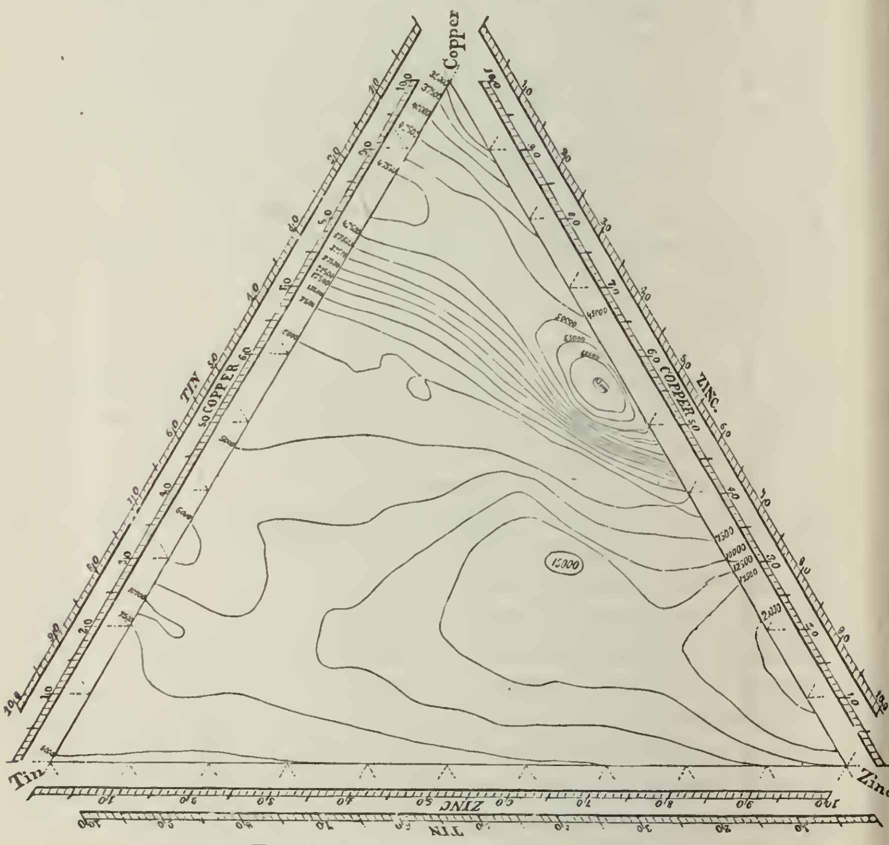

Fig. 3.—Copper-tin-zinc alloys.

research. When the figures thus obtained had been entered in the triangular map, lines of equal strength, of equal ductility, or of equal resistance, could be drawn, as, in topographical work, lines of equal altitude are drawn, and the map becomes thus a useful representative of the valuable qualities of all possible alloys. Fig. 3 represents such a map of all copper-zinc-tin alloys. The scale of altitude is obtained by considering the relation of tension to torsion resistance, which is nearly 25,000 pounds per square inch (1,758 kilogrammes per square centimetre) for each 100 foot-pounds (13·82 kilogrammetres) of torsional moment for the standard test-specimen, which specimen was turned to a standard gauge, and made ⅝ inch (1·84 centimetres) diameter and 1 inch (2·54 centimetres) long in the cylindrical part exposed to strain. These facts, as determined experimentally, were subsequently still better exhibited by another method devised by Prof. Thurston for class illustration, thus: Upon a triangular base of metal, laid off as above, erect a light metallic staff, by drilling a hole for its support at each point laid down, as representative of an alloy tested; make the altitude of each of these wires proportional to the strength of that alloy. There is thus produced a forest of wires, the tops of which are at elevations above the base-plane proportional to the strength of the alloys studied. Similar constructions may be made to represent the elasticity, the ductility, or any other property of these alloys. Next, fill in between these verticals with clay, or, better, with plaster, and carefully mould it until the tops of all the wires are just visible, shining points in the now smooth surface of the model. The surface thus formed will have a topography characteristic of the alloys examined, and its undulations will represent the characteristic variations of quality, with changing proportions of the three constituents. This was made for Prof. Thurston, and was cast in the alloy which is the subject of this paper, the plaster cast made as above being used as a pattern, and this cast is used in lecture-room illustrations, and is supplied to other institutions.

Fig. 4 is a good representation made from a photograph of the model for the American Association for the Advancement of Science. The alloys studied were originally intended to furnish data during a preliminary research that should serve as a guide in a later and more complete study of this important and intensely interesting field of investigation; these alloys were purposely made precisely as the brass founder is accustomed to make them. The data obtained were conse-

quently exceedingly variable, and the results of this work indicated as one, and not the least valuable of deductions from it, that the same alloy, and especially where the proportion of copper is great, may give very different figures when tested, according as it is more or less affected by the many circumstances that influence the value of all brass foundry products. But, allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figs. 3 and 4, about a point not far from copper = 55, zinc

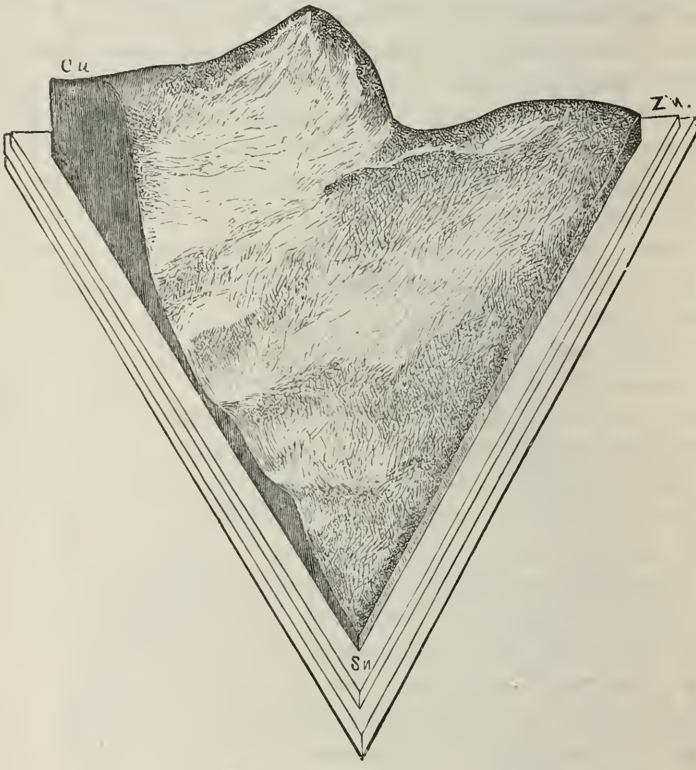

FIG. 4.—MODEL OF STRENGTH OF ALLOYS.

= 43, and tin = 2. This point is encircled in the map, Fig. 3, by the line marked 65,000 pounds per square inch (4,570 kilogrammes per square centimetre) tenacity, and is represented on the model, Fig. 4, by the peak of the mountain seen at the farthest side—the copper-zinc side as shown. This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so formed as to produce sound and pure metallic

alloys, with such prompt cooling as shall prevent liquation, is the strongest bronze that man can make.

Prof. Thurston finally made this alloy, and of it constructed the model represented in the last figure. It is a close-grained alloy, of rich color, fine surface, and takes a good polish. It oxidizes with difficulty, and the surface then takes on a pleasant shade of statuary bronze green. Testing it, it was found to have considerable hardness, but moderate ductility, though tough and ductile enough for most purposes; it would forge if handled skillfully and carefully, and not too long or too highly heated; had immense strength, and seemed unusually well adapted for general use as a working quality of bronze. In composition, however, it is seen to be a brass, with a small dose of tin. The alloy made as representing the alloy for purposes demanding toughness as well as strength contains less tin than the above composition, Cu 55, Sn 0·5, Zn 44·5. It had a tenacity of 68,900 pounds per square inch (4,844 kilogrammes per square centimetre) of original section, and 92,136 pounds (6,477 kilogrammes) on fractured area, and elongated 47 to 51 per cent., with a reduction to from 0·69 to 0·73 per cent. of its original diameter. No exaltation of the normal elastic limit was observed during tests made for the purpose of measuring it if noted. This alloy was wonderfully homogeneous, two tests by tension giving exactly the same figures, 68,900. The fractured surface was in color pinkish-yellow, and was dotted with minute crystals of alloy produced by cooling too slowly. The shavings produced by the turning tool were curled closely, like those of good iron, and were tough and strong. This alloy and the "Tobin Alloy," Cu 58·22, Sn 2·30, Zn 39·48, are good working metals, the latter being capable of great improvement by skillful working either hot or cold, and thus of obtaining a tenacity of over 100,000 pounds per square inch (7,344 kilogrammes per square centimetre).

Following the inequalities exhibited by the map, we notice the fact that the line of maximum elevation crosses the field from about Cu 50, Zn 50 to Cu 85, Sn 15, is included in a band bounded by the formulas $M = Z + 4t = 50$, and $M = Z + 3t = 55$, in which Z is the percentage of zinc present in any triple alloy of that series, and T is the percentage of tin. It has been stated that along this maximum line the tenacities of the alloys should be at least $T_m = 40,000 + 500z$ in pounds on the square inch, or $T_m^1 = 2,812 + 35·15z$ in kilogrammes on the square centimetre. Thus, taking the last line,

which contains the strongest but least ductile compositions, we find the following tenacities: The alloy $Z = 1$, $T = 18$ will also contain Cu $= 100 - 19 = 81$, and this alloy, Cu 81, Zn 1, Sn 18, should have a tenacity of at least $T_m = 40{,}000 + (500 \times 1) = 40{,}500$ pounds per square inch; $T_m{}^1 = 2{,}812 + (35{\cdot}15 \times 1) = 2{,}847$ kilogrammes per square centimetre. The alloy Cu 60, Zn 5, Sn 16 should have at least the strength $T_m = 40{,}000 + (500 \times 5) = 42{,}500$ pounds per square inch; $T_m{}^1 = 2{,}812 + (35{\cdot}15 \times 5) = 2{,}988$ kilogrammes per square centimetre, etc. These are rough working formulas, that, while often departed from in fact, and, while purely empirical, may prove of real value in framing specifications. Where the composition is that of brass rather than bronze this line of alloys exhibits more toughness. The alloys Cu 55, Sn 2, Zn 43, and Cu 55, Sn 0·5, Zn 44·5 were quite excellent in this respect. Tin reduces ductility more rapidly than does zinc.

Prof. Thurston deduces the following equations, $T = 30{,}000 + 1{,}000\ t + 500\ z$ and $T^1 = 2{,}109 + 70{\cdot}3\ t + 35{\cdot}15\ z$, which he says cover the whole field of copper-tin-zinc alloys useful to the engineer, *i. e.* in which $4\ t + 2 < 50$. But it must be understood that this approximate statement of tenacities is a minimum for well made alloys, and is also applicable only to those containing a larger percentage of copper than to those which lie along the maximum line; the alloys to which they apply are, however, the best alloys for general use. The ductility of these alloys is a subject of quite as much interest to the engineer as their strength, and in this quality the triple alloys are as variable as any other. There is a territory which is valueless as far as ductility is concerned, and it is bounded by a slightly curved line, to which a line having the equation $2{\cdot}5\ t + z = 55$ is nearly tangent. The alloys lying along this line have nearly equal ductility, extending, according to the measurements obtained by the autographic machine, about ·03 per cent. Above this line is another having nearly the equation $4\ t + z = 50$, which last line is that of equal ductility for alloys exhibiting extensions on the strain-diagram of 3 per cent. Still nearer the pure copper corner fairly representing alloys containing about $3\frac{3}{4}\ t + z = 48$, and along which the extensions as per strain-diagrams were 7·3 per cent., and another such line extending from the standard gun metal compositions on the one side to the tough Muntz metal on the other—Cu 90, Sn 10, to Cu 55, Zn 45—of which the equation is nearly $4{\cdot}5\ t + z = 45$—represents and identifies alloys averaging, as cast during this initial

research, an extension of 17 per cent. These lines are best seen on the sheet of extension, Fig. 5. All alloys lying above the line taken here as a boundary line give figures for tenacity that are usually considered good; they all exceed 30,000 pounds per square inch (2,109 kilogrammes per square centimetre).

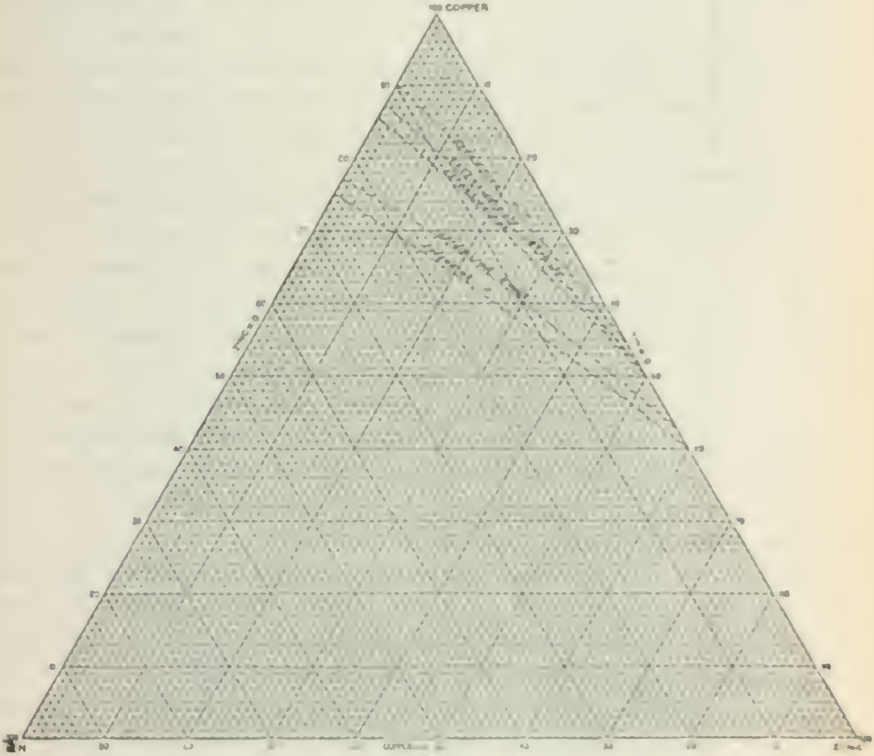

FIG. 5.—DUCTILITY OF COPPER-TIN-ZINC ALLOYS.

It is seen that the addition of tin and of zinc to cast copper increases the tenacity, at least up to a limit marked by the line $3t + z = 55$, and that the influence of tin is nearly twice as great as that of zinc, while the limit of useful effect is not reached in the latter case until the amount added becomes very much greater than with the former class, the copper-tin alloys. Brasses can be obtained which are stronger than any bronzes, and the ductility of the working compositions of the former class generally greatly exceeds that of the latter. So sensitive is zinc to the presence of tin that M. Bischof states that he can detect the addition of one part of tin in

ten millions of pure zinc. The range of useful introduction of tin is very much more restricted than with zinc; alloys containing 12 to 15 per cent. tin are so hard and brittle as to but rarely find application in the arts, while brass, containing 40 per cent. zinc, is about the toughest and most generally useful of all the copper-zinc "mixtures." The moduli of elasticity of these alloys are remarkably uniform, more than one-half of all those here described ranging closely up to fourteen millions, or one-half that of well made steel wire, such as is used in the New York and Brooklyn bridge. The moduli gradually and slowly increase from the beginning of the test to the elastic limit.

The fracture of these alloys is always indicative of their special characteristics. Those broken by torsion in the autographic machine were, if brittle, more or less conoidal at one side of the break; ductile alloys yield in similar circumstances by shearing in a plane at right angles to the axis of the test piece; the former resembles cast-iron, and the latter have the fracture of wrought-iron. Every shade of gradation in this respect is exhibited by an observable modification of the surface of fracture, varying from that characteristic of extreme rigidity and brittleness, through an interesting variety of intermediate and compound forms, to that seen in fracture of the most ductile metals.

Thus the field has been reconnoitered by Prof. Thurston, and Mr. Coster has been guided in his researches by the indications here given, and thus has been saved a great deal of time and money We may now proceed to give an abstract of these labors.

Part IV.

The Strongest Bronze.

Prof. Thurston having laid down the boundaries within which the useful alloys of copper-tin-zinc are to be found, Mr. Maurice I. Coster, M.E., under his direction and supervision, carefully investigated the enclosed field and embodied the results of his labors in a paper of which the following is an abstract. Mr. Coster began his work by forming two series in order to fix more accurately this particular part of the field. When its boundaries were approximately defined, three other series were proposed, in which the alloys were made to differ by smaller percentages.

The copper employed in these investigations was the best Lake Superior metal; the tin was the best Banca, and the zinc the best Lehigh which could be procured in the market. The total amount of metal weighed out for each bar was 4·5 kilogrammes for every series except the second, in which it was 1,500 grammes. The weighings were made in the Physical Laboratory of the Stevens Institute of Technology, on the U. S. standard balance to within 10 milligrammes. The castings were made in a vertical iron mould 28 inches long and of 1 square inch internal cross-section. The inner surface of the mould was coated with a mixture of charcoal dust and water. In the third and subsequent series, plumbago was substituted for charcoal dust, and this gave more satisfactory results, the friction between the bar and the mould being thereby nearly eliminated.

The method of casting was as follows: The copper was first melted and raised to a sufficiently high temperature to allow the addition of tin without solidifying. The zinc, after being wrapped in a piece of paper, was introduced in the molten metal and kept below the surface by means of a pair of tongs, thus preventing its coming in contact with the air and its consequent volatilization. Charcoal dust in sufficiently large quantities was thrown into the crucible and thus oxidation was almost prevented. The metal was then well stirred with a stick and the crucible taken out of the furnace. A few minutes before pouring, the tin was added and the alloy well agitated to cause a thorough mixture of the metals. The dross having been removed from the surface, the metal was then poured into the mould—immediately after the temperature test, to be described presently, was made—and then allowed to cool. It was deemed advisable to determine for future reference the temperatures at which the alloys were cast, since this is supposed to have some influence upon their strength and other qualities. The method employed was the same as that used by Messrs. Levi and Kunzel in their experiments on "phosphor bronze." As soon as the casting was taken out of the mould the series number was marked on it in black paint and the top and bottom parts were designated by the letters A and B respectively. This distinction was made to enable the observer to determine the difference in properties of various portions of the bar, and also to assist him in detecting the extent of the liquation which took place in some of the castings.

The first test to which the bars were subjected was by transverse stress; after this, the remaining portions of the bars were turned in a

lathe for tensile specimens. From the results of the transverse and tensile tests, curves were constructed whose ordinates represent the loads and the abscissas the corresponding deflections and elongations. By comparing these curves the general properties of the alloys can be studied, and the experienced eye can tell at a glance if the metal represented by a curve will answer the purposes for which it is intended to be used. The fractures having been described, after the test pieces were broken they were turned into specimens to be tested by torsion. Pieces of about one inch in length were cut off the cylindrical part of the broken tensile specimens for use in the determination of specific gravity. They were cut off near the middle of the bar and as far from the fractured ends as was possible, in order to obtain the portions which were the least disturbed. The torsion specimens were made one and three-eighths inches at the ends and one inch between the shoulders and five-eighths diameter; thus,

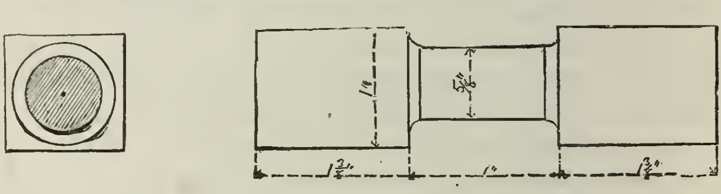

FIG. 6.—TEST-PIECE.

Some of the very brittle alloys could only be turned to a cylinder of about one inch in diameter, while others could not be turned at all. These were then ground to a cylindrical form on an emery wheel. In calculating the results it was assumed that the torsional moments and resiliences vary directly as the cubes of the diameters of the test-pieces, and the figures obtained were reduced in this manner that they might be compared with those of the standard diameter. The machine used for the torsion tests was Prof. R. H. Thurston's Autographic Recording Testing Machine, (Fig. 7.) It consists of two strong wrenches carried by frames and which depend from axes in the same line, but not connected with each other. To one of the wrenches is fixed an arm which carries a weight at the lower end. Motion is given to the other wrench by means of a worm and gear. Two centres are placed in the axis of the machine and project into the recesses of the wrenches; one of them is fixed, while the other is movable and has a spring pressing behind it. The specimen to be tested is placed between the centres and fastened to the wrenches by a set of steel wedges. Its axis is thus

made to coincide with that of the machine, a result which could not always be attained with the steel chucks formerly used. A guide curve is secured to one of the frames, and is of such a form that its ordinates are proportional to the torsional moments exerted by the weighted arm, while moving up the arc, to which the corresponding abscissas of the curve are proportional. A pencil-holder is carried

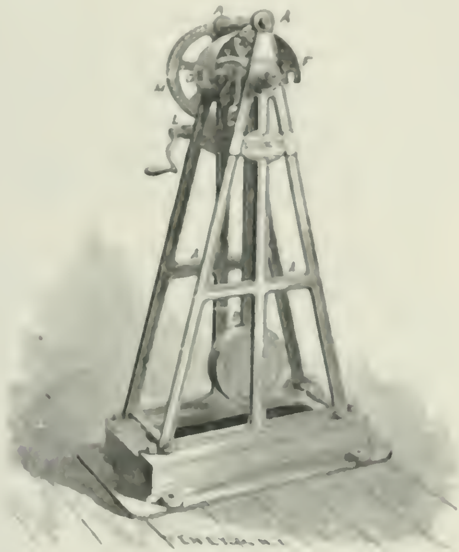

FIG. 7.—AUTOGRAPHIC TESTING MACHINE OF PROF. THURSTON.

on this arm and the pencil is pushed forward by the guide-curve as the arm is forced out of the vertical position. The movement of the pencil is thus made proportional to the force which, transmitted through the test-piece, produces deflection of the weighted arm. The other wrench carries a cylinder, upon which the paper receiving the record is clamped, and the pencil makes its mark on the table thus provided. This table having a motion relatively to the pencil, which is precisely the relative angular motion of the two extremities of the tested specimen, the curve described upon the paper is always of such a form that the ordinate of any point measures the amount of the distorting force at a certain instant, while its abscissa measures the distortion produced at the same instant. The diagrams obtained by this machine, when interpreted, will give relative measures of the strength, ductility, and resilience of the materials, and will also

indicate their degree of homogeneity. Some of the alloys of the first and second series were so weak that no curves indicating their properties could be obtained if they were tested with the large weight attached to the machine. A weight of 30 pounds was then substituted and in several cases no auxiliary weight was used, the weight of the arm alone being sufficient to break the specimen.

All broken specimens were carefully stored in trays made especially for this purpose, and can be referred to at any time. The turnings of the tensile pieces were all preserved in packages and laid aside for chemical analysis, The outside and inside turnings of the tension-pieces were preserved separately for analysis, in case it should be desired to determine the difference in composition near the surface and near the centre for those alloys where lateral liquation had taken place.

In order to ascertain what results would be obtained by casting together brass and bronze of known properties, the first series of triple alloys was prepared in proportions based upon results obtained in Prof. Thurston's work as the strongest, weakest, most and least resilient of alloys; and by various combinations of these, twelve alloys (including "Tobin's alloy") were obtained. As the writer confined himself in his own labors to the results obtained by the Autographic Recording Machine, we will omit the statement of results obtained in the transverse and tensile tests, fully described by Mr. Coster in his paper, and pass to those results which he obtained from the torsion tests, which were strictly concordant with and more instructive than the former.

1st Series.—The areas of the autographic strain-diagrams were computed with an Amsler planimeter, and the resilience from the data thus found. No. 5 (Cu. 88·135, Sn. 1·865, Zn. 10), was made up of the most resilient bronze and brass, and its resilience was less than that of either of its components. No. 6 (Cu. 45, Sn. 23·75, Zn. 31·25) composed of the least resilient bronze and brass, was less resilient than the brass, but more so than the bronze. No. 7 (Cu. 66·885, Sn. 1·865, Zn. 31·2), formed of the most resilient bronze and the least resilient brass, was much less resilient than the bronze, but considerably more so than the brass. No. 8 (Cu. 66·25, Sn. 23·75, Zn. 10), was made of the least resilient bronze and the most resilient brass. It was less resilient than either the bronze or the brass. No. 4 was so brittle that it was not tested at all. The greatest resistance to tor-

sion of all the bars of the series was exhibited by No. 7, and the mean of its torsional moments exceeded that of all the others. It was of a more homogeneous structure, and may be considered the best alloy of the series. No. 4 was the most brittle of the series, and also the least resilient. No. 5 was the most ductile and the most resilient. No. 12 (Cu. 58·22, Sn. 2·30, Zn. 39·48) was shown by all the tests to be the strongest alloy tested in the Mechanical Laboratory. It exceeded good wrought iron in strength, and was sufficiently resilient to resist shocks. Its modulus of elasticity, as calculated from the transverse test, is 11,500,000. From the results obtained by the alloys of this series, it is evident that it does not necessarily follow that two alloys which are separately good and strong, or poor and weak, and are composed of different metals, will, when cast together, give an alloy which is similarly strong or weak.

2d Series.—This series was made up to enable a closer approximation to be made before investigating details. In this set 36 alloys were made by allowing all possible combinations obtainable by a difference of 10 per cent. in three metals. They were 9 inches long and from most of them two specimens were obtained. It was attempted to compress the bars of this series, while fluid; but it was found impracticable owing to the small amount of metal. In the few cases in which the compression was made, the effect was so trifling that no increase of strength could be noticed. In general, the bars of this series were not as strong as those of the first series; this may have been due to the fact that the other bars were nearly three times as long and were thus cast under a greater pressure. From the triangle of maximum torsional moments we notice that if the amount of tin does not exceed 40 per cent., the alloys are strengthened by an increase of copper up to 20 per cent. If a further addition of copper takes place, the alloys gradually become brittle, and when the copper amounts to 50 per cent., compositions are obtained which are so brittle as to be practically worthless. If more copper is added the alloys begin to increase in strength until a maximum strength is attained for the greatest percentage of copper in their series, *i. e.*, 80 per cent. When the amount of tin exceeds 40 per cent. the alloy becomes weaker as the percentage of copper is increased. Up to 20 per cent. of copper an increase of tin causes a decrease of strength and an increased ductility. Between 20 per cent. and 40 per cent. of copper it seems that the alloys become stronger for an increase of tin up to 20 per cent. They then

become weaker as the tin is further increased. When the amount of copper exceeds 40 per cent. an increase of tin again appears to weaken the alloy; this is only true when the least quantity of tin amounts to 10 per cent., as in this series. The results of the tests of this series show that more than five-sixths of the possible alloys are comparatively worthless and that it would not be worth the expense and time necessary to investigate this part of the field more fully.

3d Series.—This series consisted of 24 bars of the same length as those of the first series. A line was drawn from 45 per cent. of copper on the zinc side of the triangle to 72·5 per cent. of copper on the tin side. These points represent the percentage at which the change of color and increase of strength in the brass and bronze alloys takes place. The alloys of this series were all located in the portion of the field containing all the more useful compositions and they were made to vary in regular order by 5 per cent. The castings of this and subsequent series had smoother surfaces than those of the preceding and none of the bars were broken in the mould. A volatilization of the zinc took place during the pouring of the molten metal in the first three numbers of the series. Mr. Coster found a great difference in the results obtained from the upper and lower ends of the bars; the upper end giving the more favorable results; thus, in one case, the upper end had a maximum abscissa of 53·2° while the lower end was turned through an angle of but 9·9° when it broke. The great difference between the curves of these two portions of the bar can be imagined when it is known that the former had an ordinate of 0·92 inch at the elastic limit and a maximum ordinate of 1·76 inches, while the other end had for its ordinate at the elastic limit 1·38 inches and for a maximum ordinate 1·56 inches. The general laws followed by the curves representing the properties of the alloys of copper, tin, zinc were approximately determined from the results of the test of this series. For a certain amount of copper (when this exceeds 50 per cent.) an addition of tin increases the brittleness, while zinc increases the ductility of the alloy. If the amount of copper is increased it is necessary also to increase the tin in a certain ratio in order to obtain an alloy of about the same percentage of ductility. It was shown by the result of tests of this series that 5 per cent. of tin will cause the alloy to be brittle, unless it contains about 65 per cent. of copper. When the composition has 80 per cent. of copper, 10 per cent. of tin will make it quite ductile, while 15 per cent. of tin will render it rather

brittle. Hence the amount of tin necessary to make a useful and strong alloy, when there is 80 per cent. of copper, lies somewhere between 10 per cent. and 15 per cent, and an alloy composed of Cu 80, Sn 12·5, Zn 7·5 will very nearly represent the best proportions.

4th Series.—This series consisted of but five alloys which were chosen without regard to regularity in difference of composition, but to determine some doubtful points previous to the preparation of the final series. No. 1 (Cu 55, Sn 0·5, Zn 44·5) contained but 0·5 per cent. of tin and is the only instance in the entire investigation where so small an amount of any of the metals was introduced in an alloy. This was done in order to ascertain the effect of so small a percentage when added to an alloy of known properties. This alloy was brass (Muntz metal, nearly), and 0·5 per cent. of tin was substituted for zinc, thus leaving but 44·5 per cent. of zinc. The smallest quantity of zinc in any of the bars of the series was 2·5 per cent. in No. 5 (Cu 82·5, Sn 15, Zn 2.5). The weighings, castings, etc., were made as before. The great difference in ductility between the two ends of the bars, alluded to in the preceding series, was more marked in No. 2 (Cu 67·5, Sn 5, Zn 27·5) than in any other alloys thus far tested. The upper end, No. 2 A, was turned through an angle of 70·8°, while the lower end, B, broke after it was turned through 7·5°, the latter being only about 10 per cent. of the former. This difference of structure was exhibited, in a more or less marked degree, by all the bars of this series.

5th Series.—From the results of the preceding series, it was concluded that the most useful alloys which remain to be investigated are located between the line drawn from 88 per cent. of copper on the bronze side of the triangle to 65 per cent. of copper on the brass side, and from 83 per cent. of copper on the bronze side to 55 per cent. on the brass side. The alloys in this part of the triangle were now made, varying by 2·5 per cent., omitting those which had already been tested and a few which were not absolutely necessary to the determination of the laws of variation of strength. The series consisted of twelve bars of the same length as those of the 1st, 3d and 4th series. No changes were made in the methods of weighing or casting. The results obtained fully confirmed the previous determinations. It was found that, in nearly all the bars, the upper portion was considerably more ductile than the lower and also generally stronger. All the bars of this series were strong alloys; the strongest, No. 1 (Cu 60, Sn 2·5, Zn 37·5), had a mean maximum torsional moment of 216 foot-pounds,

and the weakest, No. 7 (Cu 72·5, Sn 10, Zn 17·5), 15.2 foot-pounds. It appears from these results that all the alloys located between the lines forming the boundaries of the set of compositions experimented on in this series are useful and strong. Commencing with the strong brasses on one side of the triangle, greater strength is obtained when any appreciable amount of tin is added: as the quantity of tin is increased, the alloys continue to be superior in strength to either the brasses or the bronzes; but their strength gradually decreases with the diminution of the amount of zinc, if the alloy contains more than 60 per cent. of copper, until we obtain the strong bronzes on the other side of the triangle. An addition of tin for the same amount of copper, if this does not exceed 30 per cent., increases the ductility of the alloy. In alloys containing 40 per cent. of copper a substitution of tin for zinc does not seem to affect the ductility either one way or the other. If the alloys contain more than 40 per cent. of copper an increase of tin always causes a decrease of ductility. The most ductile alloy was No. 8 B, 2d series (Cu 10, Sn 80, Zn 10), which had an angle of torsion of 418·4°; none of the other alloys tested contained such a large quantity of tin. From the percentage of extensions of the alloys having a torsional moment of more than 150 foot-pounds, and strength of more than 35,000 pounds per square inch, four curves of maximum strength with a certain percentage of extension have been constructed. The lowest curve thus plotted on the triangle has an extension of 0·03 per cent. and connects the points representing the strong brittle alloys. It starts at 43 per cent. of copper on the brass side and cuts the bronze side of the triangle at 77 per cent. of copper. The other curves have an extension of 3, 7·3, and 17 per cent. respectively. They all appear to converge to a point to the right of the brass side and agree nearly with arcs of circles of about 14 inches radius. By means of these curves of extension alloys of different degrees of ductility can be selected. (See Fig. 5.)

General Remarks.—The effect of tin upon alloys of copper and zinc can be compared to that of carbon on wrought-iron. Commencing with brass of about 55 per cent. of copper, which is of itself ductile and strong, we obtain by the addition of a small percentage of tin an alloy of much greater strength, having a higher modulus of elasticity, but not quite as ductile. By further addition of tin, up to about 2.5 per cent., the alloy becomes gradually less ductile, but it increases in strength. If more tin is added we obtain compositions which become

more brittle as the tin is increased, and at the same time decrease in strength. A slight modification of proportions often causes very great changes in the properties of the alloys, as has been noticed in No. 1, 4th series, where 0·5 per cent. of tin, added to ordinary brass, resulted in giving an alloy stronger than wrought-iron.

(To be concluded.)

"THE BRITISH PATENTS, DESIGNS, AND TRADE-MARKS ACT OF 1883," IN ITS RELATION TO AMERICAN INVENTORS.

By G. MORGAN ELDRIDGE.

(Read at the Stated Meeting, Wednesday, December 19, 1883.)

On the first of the coming year a new enactment goes into operation in England, which to some extent modifies the present patent system of that country; and in view of the fact that many citizens of the United States have already taken out patents there, and that under the new law many more will probably do so, it is well to consider the condition of things under the new régime, especially since sundry contradictory, and some incorrect statements have appeared in the public prints in regard to it.

To commence with one very important point, it has come to be generally supposed that publication or introduction of a new invention may then be made there for six months, before applying for a patent—as they may be for two years in the United States—without injury to the application. This impression, however, is entirely erroneous, as the old law in that respect is unchanged, unless under circumstances which are very exceptional and do not affect the general rule.

This appears by section 26, which provides that "Every ground on which a patent might at the commencement of this Act be repealed by *scire facias* shall be available by way of defence to an action of infringement, and shall also be ground of revocation."

One of the exceptions relates to an exhibition of the invention at an industrial or international exhibition, and another to patents, designs, and trademarks in such foreign States as have made mutual arrangements with England for that purpose; and the precision with which these exceptions are stated, only more clearly defines the general rule.

Section 39 provides as follows: "The exhibition of an invention at an industrial or international exhibition, certified as such by the Board of Trade, or the publication of any description of the invention during the period of the holding of the exhibition, or the use of the invention for the purpose of the exhibition in the place where the exhibition is held, or the use of the invention during the period of the holding of the exhibition by any person elsewhere without the privity or consent of the inventor, shall not prejudice the right of the inventor or his legal representative to apply for and obtain provisional protection and a patent in respect of the invention or the validity of any patent granted on the application, provided that both the following conditions are complied with, namely:

"*a.* The exhibitor must, before exhibiting his invention, give the comptroller the prescribed notice of his intention to do so; and,

"*b.* The application for a patent must be made before or within six months from the opening of the exhibition."

To analyze this, which is strictly exceptional, and therefore goes to the extent of its letter, and no further, will show within what narrow limit even this privilege is allowed.

The right to apply for a patent, and the validity of the patent itself when granted, are not prejudiced only in the case that the exhibition is at an international or industrial exhibition, certified to be such by the Board of Trade; that the exhibitor before exhibiting his invention, has given the comptroller the prescribed notice of his intention; that the invention is used only for the purpose of the exhibition and in the place where the exhibition is held; that during the holding of the exhibition any use by any person elsewhere is without the privity or consent of the inventor; that publication of a description of the invention be made only during the period of the holding of the exhibition; that application for a patent be made within six months from the opening of the exhibition: or, to state the converse of the proposition, if the invention be exhibited at an exhibition not so certified, or at such certified exhibition without the prescribed notice to the comptroller, or at any other place or time or for any other purpose, than at and during the holding of the exhibition, and for the purpose of the exhibition; or if it be used by any person elsewhere during the holding of the exhibition with the privity or consent of the inventor; or if any description of the invention be published except during the period of the holding of the exhibition; or if application be not made within six months,

the right to a patent is lost, and the privilege of six months is practically limited to the period of the exhibition, as will plainly appear, because, the use of the invention by the inventor on any day after the close of the exhibition takes him out of the exception of this clause; the use of the invention by any person anywhere on any such day, with or without his knowledge, has the same effect; and a publication of a description of the invention, though not producing that result while the exhibition remains open, becomes thus operative the day after it has closed, and bars his rights.

The other exception is one which is not likely to become operative in the United States.

Section 103 provides, that if any arrangement is made with any foreign State for the mutual protection of inventions, designs, or trade-marks, the person who has applied for protection in such State shall have priority over other applicants, in the case of a patent for seven months, and in the case of a design or trade-mark for four months, and that publication of a description of the invention or the use thereof in England during that time shall not invalidate a patent therefor, this exception being limited to States to which it shall be declared applicable by Order in Council, which is revokable at discretion.

It is not probable that this provision will ever become applicable to the United States, because such mutual arrangement could enure only to the benefit of citizens of the United States, and not at all to subjects of England, who have now not only seven months, but two full years during which they may apply for patents without prejudice by reason of publication or use, and therefore there is nothing to be given in return for the privilege.

The only additional exception is that the communication of an invention for an improvement in instruments or munitions of war to the Secretary of State for investigation, and anything done by him in such investigation shall not prejudice the rights of the inventor.

Any person or persons, English or foreign, may apply for a patent. The Act provides (§4), that the applicant shall declare that he is in possession of an invention of which he claims to be the true and first inventor, and for which he applies for a patent. No definition is given of the word inventor, but an invention is defined to be (§46) any manner of new manufacture the subject of letters patent within Section six of Chapter three of the twenty-first year of King James the First, and is stated to include an alleged invention, which leaves the meaning

of the word inventor as under the old law in which it is synonymous with introducer. It is to be noted that while the applicant declares that he is the true and first inventor, the word original is nowhere used; so that plainly, under the new law, as under the old, the original inventor has no rights which the introducer is bound to respect.

Amendments and disclaimers may be made, substantially as reissues and disclaimers are allowed under the American system, it being provided that no amendment shall be allowed that would make the specification substantially larger than or different from the invention originally covered, with the difference, that leave to amend is conclusive as to the right of the party to amend except in case of fraud, which takes away the question, so important in the United States, of variance between the original patent and the reissue; that a disclaimer may be made pending a suit, the hearing on which is postponed for that purpose, and then goes on as if the disclaimer had been previously made; and that, a very important difference (Section 20), "Where an amendment by way of disclaimer, correction or explanation has been allowed under this act no damages shall be given in any action in respect to the use of the invention before the disclaimer, correction or explanation, *unless the patentee establishes to the satisfaction of the Court that his original claim was framed in good faith and with reasonable skill and knowledge.*"

While, undoubtedly, the drift of the decisions of the Supreme Court of the United States in regard to reissues is to the public interest, it is worthy of consideration whether the exception in Section 20 might not, if introduced here, serve the ends of justice better than they are served by the present law, which sometimes works great hardship.

Compulsory licenses may be ordered by the Board of Trade on terms fixed by it in case—

a. The patent is not being worked.

b. The reasonable requirements of the public are not supplied.

c. "Any person is prevented from using to the best advantage an invention of which he is possessed;" which last opens a wide door.

It would be well to consider whether some provision of this nature might not advantageously be introduced in the United States.

A patent under the new law binds the Crown, but the invention may be used by the Government or by Government contractors on terms to be agreed upon, or, in default of an agreement, on terms to be settled by the Treasury after hearing the parties interested.

An invention may be used on a foreign ship in British ports, not-

withstanding an English patent, provided that similar privileges are allowed to British ships in the State to which such ship belongs.

Any person who, by advertisement or otherwise, threatens prosecution for infringement of a patent, and does not bring a suit, is liable to an action for damages if the thing as to which he makes the threat be not an infringement of his patent, and he may be restrained by injunction from the continuance of such threats, which provision, if in force here, would save annoyance.

A patent is to be for one invention only, but it is not ground of objection that it is for more than one. It must have a claim, and may have more than one.

Section 26 (8) provides, "Where a patent has been revoked on the ground of fraud the comptroller may, on the application of the true inventor made in accordance with the provisions of this Act, grant to him a patent in lieu of and bearing the same date as the date of revocation of the patent so revoked, but the patent so granted shall cease on the expiration of the term for which the original patent was granted."

This, to this extent, takes out of the Patent Office and into the Courts the question of conflicting claims to the same invention, and where it is there determined that the holder of the patent is not the one entitled it, not merely revokes the patent wrongly held, but practically transfers it, for the remainder of its term, to the successful litigant who is decreed to be its proper owner.

It is worthy of consideration whether some provision of this nature might not be adopted in the United States, by which proceedings in interference, now so productive of expense and fruitless of result, might be transferred from the Patent Office, which can now only give to the applicant who appears best entitled, a patent which is again newly assailed so soon as the patentee attempts to enforce it, to a Court which could bring before it all the parties claimant, decide in favor of one and grant him a patent, and by decree binding on all the world, to be noted on the patent, debar defence to that patent on any ground which would have entitled either of the others to a patent for that invention. Such parts of each application as were not in interference could proceed, and patents on them could be issued in the regular way, and only the precise question in interference would come before the Court and be the subject of its decree. The Patent Office could settle the form

of the patent to which some one of the contestants would be entitled, and in that form turn over the question to the Court.

This would probably be no less expensive than the interference or the generally consequent suit, but it would be only as expensive as one of them and would definitively and perpetually close controversy upon the subject.

Every application filed is referred to an examiner, who reports whether the nature of the invention has been fairly described, whether the papers have been prepared in the prescribed manner, whether the title sufficiently indicates the subject matter of the invention, and, in case there is on file at the same time an application bearing the same or a similar title, whether they both comprise the same invention, in which latter case, if such is found to be the fact, "the comptroller may refuse to seal a patent on the application of the second applicant."

Opposition to the grant of a patent may be made by any person on the ground of the applicant having obtained the invention from him; or on the ground that the alleged invention is covered by an existing English patent or a prior application, but on no other ground; which provisions define the limit of investigation as to the novelty of the invention, and leave in operation, with these exceptions, the present system of granting to any one a patent for anything he asks, with no approach to the advantages which are offered to the applicant for a patent in the United States by the system which is in operation here.

These advantages, great as they are, are by some not clearly understood, and therefore not fully appreciated.

It is to be borne in mind that a patent whose claim covers a thing previously known or used is inoperative and invalid. Such prior knowledge or use may be divided into two classes; a published description in some patent or other publication; and the manufacture, use or sale of the thing claimed as new, as to which there has been no published description.

As to the last, it is in its nature that it cannot with certainty be known to any person by the most careful research, for a use of a thing in a factory or shop, or by a limited number of persons outside of such place, may be so far public as to invalidate a patent for it and at the same time so far private that only by the merest accident can it be discovered by any one elsewhere.

As to such obstructions, both systems stand on an even footing, and they are to be compared only by their relation to published matter.

Considered only in such relation, if a patent claim covers matter so published the patent is void, otherwise it is valid, and that equally in both countries. The experience of every one who has taken out a patent in the United States will show him that the case is rarely exceptional in which the claims as first presented are not liable to the objection that they cover old matter, and that therefore the patent, if issued in that form, would be invalid.

In England the patent would be issued in that form, and the patentee would be left to discover, at the end of a law-suit, and after he had exhausted his means in the introduction of his invention, in which he supposed himself protected, that his patent was inoperative and his protection had failed.

In the United States the application is referred to the examiner, who has charge of that branch of that subdivision of that class of inventions, who has before him the results of the careful research, for years, of the publications relating to that special detail of the subject brought down to the latest date, and he advises the applicant as to every objection which can be found to his claims in any publication in the world, which objection, if well founded, would invalidate his patent if issued in that form, whenever and by whomsoever discovered.

If the objection be not well founded the applicant can obtain his patent regardless of it. If it be well founded and goes to the entire extent of the novelty of the supposed invention, the applicant finds that, though he was an original, he was not the first inventor, and he retires from the contest, which is the best for him; if he has nothing, the sooner and the more cheaply he learns it the better.

If, as is generally the case, he has really invented something new—but has claimed more than was new—he learns what portion of it is old, and he limits his claim to that which is really his; and he has a very good assurance that, so far as published matter is concerned, when he takes out his patent in this form, he has that which will effectually prevent any one from making, vending, or using the thing covered by his claims.

If, when the process of elimination is completed, he finds that what is left is of no value to him, he need go no further; which, again, is good for him; he knows, or can know, exactly upon what ground he stands.

All this he obtains for the preliminary fee of fifteen dollars paid into the Patent Office; a result which he could not obtain otherwise for that

sum, nor scarcely for any sum. No individual research can cover the ground so well as it is covered by the system of minute subdivision of the Patent Office, and no approach to it could be made at the price; and, in default of it, the patentee is left to obtain the information when the cost of it may be his destruction.

If the patentee supposes—as from ignorance many suppose—that he acquires by his patent a right to make the whole machine of which his claim covers a part, and proceeds upon that presumption, he may thus get into trouble. A patent authorizes a man to do nothing, but only enables him to prevent another from doing something, and no system of government protects a man against the consequences of his own ignorance or folly.

There is an impression among some that the Patent Office habitually grants patents which cover old matter and have no novelty, but it will be found that this criticism comes from those who are uninformed as to the above proper rule of construction, or who have not examined the claims of the patents they criticise, and are therefore not aware how restricted they are and how little ground they actually cover. This is not to be ascribed as a fault but to be counted as a merit to the Patent Office. Little as the thing is, it is all of which the patentee was the original and first inventor; and little as the thing appears, it is sometimes such a little thing which bridges the gap between a machine which is a failure and one which is a success, and the patentee has the assurance that—though little—it is all that he is entitled to and that he is entitled to it.

It may be said that the Patent Office examiners sometimes fail to discover matter which makes a good objection to the claim; which is true, and is partly the result of the fallibility of all human systems and partly the result of the niggardly system pursued by the government of the United States in relation to the Patent Office producing a corps of examiners insufficient in number and in quality. In number, because not enough are provided; in quality, because experience is the only thing which can give the desirable approach to perfection, and when an examiner has obtained this experience he finds that the pay of his position is not equal to what he can gain elsewhere, and he therefore leaves his place to another who has the experience to acquire.

If the government would devote to the use of inventors the money which it receives through the Patent Office from them, this state of things would not exist. A highly meritorious and hard-working class

of officers would be increased to the number required and would be paid according to their desert, and would therefore remain in their positions; the plan of subdivision of subjects would be more thoroughly and perfectly carried out; and, as a consequence, the number of errors would be greatly diminished, and the whole system would approach in practice very nearly to the perfection which it has in theory.

CAST IRON IN STEAM BOILERS.

By S. Lloyd Wiegand.

(Read at the Stated Meeting, Wednesday, January 16, 1884.)

Public attention has been recently directed to the fact that cast iron is extensively used in the construction of boilers, and most notably in the heads of cylinder boilers. Many such boilers have flat heads, and expressions of opinions, alleging that cast iron boiler-heads to be dangerous, have been recently made, and reiterated in terms and with a frequency calculated to excite grave alarm, not only on the part of the owners and users of such boilers, but in the minds of the public generally, and to produce an impression that such boilers are necessarily a menace to property and life.

The criticisms against such structures have not assumed any such exact expressions, as to show where safety ceases and danger begins, but they have been condemned apparently without a hearing, as dangerous and treacherous always, and under every condition.

The published engineering literature throws very little light on this subject, and no recent treatise, or for that matter, old ones either, give any rule for computing the strength, or determining the proper proportions of such boiler-heads, yet thousands of them are in daily use, and more of them are being made.

That there must be some merit in them, is a reasonable inference from their extensive use, and to open a discussion on their merits and faults, and to bring to the attention of the Institute evidence of what they are capable of enduring, is the purpose of this paper.

To bring the matter more clearly to the observation of this meeting, it is proposed to repeat an experiment recently made in this City, of testing a cylindric boiler, provided with flat cast iron heads, by hydraulic pressure, and

1st. To show the limit of elasticity in force and motion of such heads.

2d. The relative strength of the heads and the riveted shell.

3d. The manner of rupture of the head by internal pressure; and

4th. The pressure required to rupture the head.

The dimensions and form of the head and boiler shell are stated upon the sectional diagram; they are further illustrated by models, made to a scale, which may serve to give a better conception of the proportions of the boiler under test.

The testing operation consists in simply filling with water, taking care to exclude all air, and afterwards gradually applying hydraulic pressure by a pump, and observing the pressure, and at the same time measuring the inflation or dilation of the head, relieving the pressure, repeating this operation several times with increasing pressure, and observing at what pressure the head becomes permanently set, or bent outward, and finally applying and observing increased pressure until the vessel breaks.

The same experiments made with a vessel exactly similar to this one, showed that no permanent set of the head took place until a pressure of 225 lbs. per square inch was applied. At that pressure the inflation at the centre of the head measured, as nearly as could be ascertained ·135 of an inch.

Before any rupture of the heads occurred, the riveted longitudinal seam leaked, so as to require very active pumping to raise the pressure above 380 lbs. per square inch, and the bursting took place at 455 lbs. per square inch, the breaking commencing at the manhole opening of one head, and extending radially outward toward the rim and the flat plate, breaking inside of and partially through the fillet, in the angle formed by the rim or flange and flat plate of the head.

As a matter of interest in this connection, there is herewith submitted to the meeting, broken parts of a flat cast iron boiler head, which wore out and survived three wrought iron shells working under pressure of 100 lbs. per square inch, and which only showed a great defect (of being in fact two layers of metal united only at the edges) when it was broken up to remelt, it having been discarded solely because of its dimensions.

It is respectfully suggested, that although cast iron has not all the properties that might seem desirable in the construction of apparatus to sustain internal pressure, it is, and will in all probability for a long time remain one of the most easily available materials for mechanical

structures, and instead of finding fault with it in general terms, and condemning its use by unmeasured terms of reproach, it is far more desirable that whatever information, of a reliable character, in reference to its proper useful and safe application to such structures is procurable, should be put in some accessible shape, and made generally known.

Entertaining these views, it is proposed that when new business is in order at this meeting, to submit the following resolution:

Resolved, That the Committee on Science and the Arts, be requested to ascertain and report the properties and strength of cast iron, as a material for the construction of boiler-heads and other vessels for retaining fluid under pressure, together with such rules for estimating the strength and proportioning of such structures, in the different forms now in use, with economy and safety, and also the proper modes of testing and using such structures, as will be useful to those practically engaged in the manufacture and use thereof.

Studies of the Aurora.—Tresca gave a flattering testimonial to the ingenuity and success of Prof. Lemström, on laying before the French Academy the results of the experiments in Lapland for producing artificial auroras. He considers that Lemström has demonstrated, by those experiments, that in extreme northern latitudes, and at a temperature of —30° (—22° F.), the polar aurora is an electric phenomenon, which may be represented by atmospheric currents of a magnitude corresponding to a current which would be produced by a Leclanché cell of moderate size. The natural manifestation of this current gives place, even in the absence of any other illumination, to a local aurora, which is visible above the apparatus, and in which can be seen the characteristic line, $\lambda = 5{,}569$. We are thus able to recognize, with complete certainty, the existence, and even the magnitude, of the electric forces which are brought into play. During the coming winter Prof. Lemström proposes to continue his researches, with the view of determining the proper construction of apparatus for giving currents of the greatest intensity; the relation between the extent of surface and the intensity of current; the variation of current with differences of latitude and with differences of altitude between the two extremities of the apparatus; the influence of the seasons; and the relations between the atmospheric current, the terrestrial current, and the magnetic variations.—*Comptes Rendus*, May 7, 1883. C.

ELECTRO-PLATING WITH NICKEL.

By William H. Wahl.

[A paper read before the Chemical Section of the Franklin Institute, Nov. 6, 1883.]

(Concluded from page 134.)

The results of extended practical trials of Mr. Weston's formula, made by the writer, have convinced him of the substantial correctness of the claims of this inventor. Where the double sulphate of nickel and ammonium is is used the addition of boric acid in the proportion of from 1 to 3 ounces to the gallon of solution gives a bath less difficult to maintain in good working order, and affords a strongly adhesive deposit of nickel. The deposited metal is dense and white, approach- in brilliancy that obtained from the solution of the double cyanide.

In 1880, J. Powell,* of Cincinnati, patented an electro-depositing solution "composed of the pyrophosphate of soda phosphate of nickel, the bisulphite of soda, and citrate of nickel and ammonia."

In the same year C. G. Pendelton,† of New York, patented the use of an acid solution of the acetate of nickel. The inventor emphasizes the caution that this solution must always be kept acid. The metallic strength of this solution is fully maintained by the solution of the anodes, and the bath consequently requires no additions of fresh salt.

An interesting suggestion is that patented in 1880 by Mr. Powell,‡ and which covers the use of benzoic acid in nickel-plating solutions. In describing his improvement Mr. Powell calls attention to the fact (?) that simple salts of nickel cannot be used on account of their failure to yield a regular deposit. He claims to have discovered that the addition of benzoic acid to any of the nickel salts, arrests in a marked degree the tendency to an imperfect deposit, and prevents the decomposition of the solution and consequently the formation of sub-salts. The amount of benzoic acid necessary to be added to the bath for this purpose is said to be $\frac{1}{8}$ ounce to the gallon of solution. He, therefore, claims "an electro-depositing solution consisting of a soluble salt of nickel, its solvent, and benzoic acid." This bath is reported to give very satisfactory results.

In the same year, Mr. J. H. Potts,|| of Philadelphia, was granted a

* Consult U. S. Pat., No. 228,389, June 1, 1880.

† Consult U. S. Pat., No. 232,615, September 28, 1880.

‡ Consult U. S. Pat., No. 229,274, June 29, 1880.

|| Consult U. S. Pat., No. 232,755, September 28, 1880.

patent for an improved solution for the electro-deposition of nickel "consisting of the acetate of nickel and the acetate of lime with the addition of sufficient free acetic acid to render the solution distinctly acid." Mr. Potts prepares his bath as follows: He precipitates the carbonate of nickel from a boiling aqueous solution of the sulphate by the addition of bicarbonate of sodium, filters and dissolves the well-washed precipitate in acetic acid, with the aid of heat.

The acetate of calcium he prepares by treating caustic lime, or the carbonate (marble-dust) with sufficient acetic acid to dissolve it with the aid of heat. The solution of these salts is acidified, slightly but distinctly, with acetic acid.

This solution, which I have worked with under a variety of circumstances, is in many respects an excellent one. It gives satisfactory results, without that care and nicety in respect to the condition of the solution and the regulation of the current which are necessary with the double sulphate solution. The metallic strength of the solution is fully maintained, without requiring the addition of fresh salt, the only point to be observed being the necessity of adding, from time to time (say once a week), a sufficient quantity of acetic acid to maintain a distinctly acid reaction. It is rather more sensitive to the presence of a large quantity of free acid than to the opposite condition; as in the former condition it is apt to produce a black deposit, while it may be run down nearly to neutrality without notably affecting the character of the work. The deposited metal is characteristically bright on bright surfaces, and requiring but little buffing to finish. It does not appear, however, to be as well adapted for obtaining deposits of extra thickness as the commonly used double sulphate of nickel and ammonium. On the other hand, its stability in use, the variety of conditions under which it will work satisfactorily, and the trifling care and attention it calls for, make it a useful solution for nickeling.

FORMULÆ FOR NICKEL-PLATING SOLUTIONS.

No. 1.

Double sulphate of nickel and ammonium............	5 to 8 parts.
Water..	100 "

Dissolve the nickel double salt in above quantity of water with the aid of heat. Cautiously add ammonia, or the sulphate of ammonium, until the solution is neutral to test-paper. This solution should be

maintained as nearly neutral as possible in use. This is commonly known in the United States as the Adams solution. It is in very general use by nickel-platers throughout the United States, and yields, where properly managed, excellent results.

No. 2.

Double sulphate of nickel and ammonium......	10	parts.
Boric acid (refined)..	$2\frac{1}{2}$ to 5	"
Water..	150 to 200	"

(Weston's solution.) The superiority of this solution is generally acknowledged. The deposited metal, as previously remarked, is almost silver-white, dense, homogeneous and tenacious, and the solution maintains its excellent working quality very uniformly in long-continued service.

The nickel salt and boric acid may be dissolved separately in boiling water, the solutions mixed, and the volume brought up to that of the formula, or the two components may be dissolved together.

No. 3.

Acetate of nickel..	$2\frac{3}{4}$	parts.
Acetate of calcium......................................	$2\frac{1}{2}$	"
Water..	100	"

To each gallon of this solution add 1 fluidounce acetic acid, 1·047 sp. gr.

To prepare this bath, dissolve about the same quantity of the dry carbonate of nickel as that called for in the formula (or three-quarters of that quantity of the hydrated oxide) in acetic acid, adding the acid cautiously, and heating until effervescence has ceased, and solution is complete. The acetate of calcium may be made by dissolving the same weight of carbonate of calcium (marble-dust) as that called for in the formula (or one-half that quantity of caustic lime), and treating it in the same manner. Add the two solutions together, dilute the volume to the required amount by the addition of water, and then to each gallon of the solution add a fluidounce of free acetic acid, as prescribed. (Potts' solution.)

No. 4.

Sulphate of nickel and ammonium........................	10 parts.
Sulphate of ammonium..	4 "
Citric acid..	1 part.
Water..	200 parts.

The solution is made with the aid of heat, and, when cool, small fragments of carbonate of ammonium should be added until the bath is neutral to test-paper.

No. 5.

Sulphate of nickel	6 parts.
Citrate of nickel	3 "
Phosphate of nickel	3 "
Benzoic acid	1½ "
Water	200 "

No. 6.

Phosphate of nickel	10 parts.
Citrate of nickel	6 "
Pyrophosphate of sodium	10½ "
Bisulphite of sodium	1½ "
Citric acid	3 "
Aqua ammonia	15 "
Water	400 "

(Powell's solutions.) These solutions yield good results, but their complex composition must debar them from general use.

No. 7.

Sulphate of nickel	6 parts.
Aqua ammonia	3 "
Water	100 "

When the nickel is dissolved, add—

Aqua ammonia	20 parts.

This bath is similar to that recommended by Prof. Boettger; it is said to be well suited for the purposes of amateurs, inasmuch as it gives good results with a platinum anode. It is worked at a temperature of 100° Fah., with a moderate current. It requires renewal from time to time, as it becomes impoverished in nickel, by addition of fresh nickel salt; it must also be kept alkaline by the occasional addition of ammonia.

No. 8.

Sulphate of nickel and ammonium	10 parts.
Sulphate of ammonium	1½ "
Water	250 "

Dissolve in boiling water and allow to cool. These proportions are recommended for coating objects of cast and wrought iron and steel.

No. 9.

Sulphate of nickel and ammonium	10	parts.
Sulphate of ammonium	2	"
Water	300	"

Dissolve as above. Recommended for coating brass, copper, tin, Britannia, lead, zinc, etc.

No. 10.

Sulphate of nickel and ammonium	6	parts.
Chloride of ammonium (sal-ammoniac)	3	"
Water	100	"

Watt* recommends for ordinary purposes the following solution, which he affirms will give in careful hands very good results. "Take say 2 ounces of pure nickel, dissolve in hydrochloric acid, taking care not to have an excess. A gentle heat will assist the operation. When dissolved, dilute the solution with 1 quart of cold water. Now add ammonia gradually, until the solution is quite neutral to test-paper. Next, dissolve 1 ounce of sal-ammoniac (chloride of ammonium) in water, and mix this with the former solution. Lastly, evaporate and crystallize slowly." The resulting salt will be the double chloride of nickel and ammonium. It is one of the earliest solutions used for nickel-plating by Smee and Gore, and is affirmed by these writers to give good results. Watt has also obtained excellent results with the double chloride. According to Smee, the simple chloride of nickel will yield a deposit having a very brilliant lustre.

I can unqualifiedly confirm the statement of Gore† that the electro-deposit obtained from a solution of the double cyanide of nickel and potassium is "nearly equal in whiteness to silver." I have obtained deposits with this solution, of such extreme whiteness and beauty as to deceive even an expert on casual inspection into the belief that they were silver. The bath, however, rapidly loses its activity and runs down, and is so difficult to manage that it is impracticable for general use. This, at least, is the opinion I have reached after many trials of it. I am informed, nevertheless that it is successfully used on the large scale in certain nickel-plating works in this country, though I have not been able to substantiate the fact.

To prepare this bath make a solution of any salt of nickel, and add cyanide of potassium solution so long as a precipitate continues to be

* Watt, *Electro-Metallurgy* (7th ed.), p. 94.
† Gore, *Electro-Metallurgy* (1877), p. 233.

formed, being careful to avoid adding an excess. Then remove the liquid either by decantation or filtration; and after several washings dissolve the precipitate almost to saturation in cyanide of potassium solution. Make a completely saturated solution and add a small quantity of free cyanide of potassium. The brownish-red solution is then ready for use.

It may be added, in conclusion, that the double sulphate of nickel and ammonium is used most generally by electro-platers with nickel.

GENERAL OBSERVATIONS.

Where the double sulphate of nickel and ammonium is used, it is important that the operator should bear in mind the caution to maintain bath as nearly neutral as possible There is a diversity of opinion the among nickel-platers upon this point, some preferring to operate with a slightly acid bath, while others prefer the opposite condition. Experience has shown that the solution will give satisfactory results either when slightly acid or slightly alkaline, and, as the chemical character of the bath during electrolysis is constantly being modified, it is manifestly impossible for the operator to do more than to keep his solution approximately in the right condition. A strongly acid solution will fail to give a deposit. When the bath therefore is found to be in this condition the addition of sufficient ammonia to restore its neutrality will bring it to working condition.

It is only by accident or carelessness, however, that the solution will become inoperative from this cause, as the chemical changes which occur in the solution of this salt, under the influence of the electrical current, and under the conditions in which it is commonly used in the plating bath, are such as to cause it to gradually assume an alkaline character. This is due to the fact that not simply sulphate of nickel, but to some extent also, sulphate of ammonium, undergoes decomposition into its proximate constituents. The sulphuric acid set free by the decomposition of the ammonium sulphate will form an equivalent quantity of sulphate of nickel by solution of the anode, while the ammonia will remain free, and gradually, as it accumulates, will impart a decided alkalinity to the bath. The more intense the current employed, the more rapid will be the decomposition of the solution and the liberation of free ammonia. As this change progresses, the quality of the work is more or less unfavorably influenced. Accum-

panying this change, especially where the current employed is irregular and at times too intense, there is also a precipitation of some of the nickel, probably in the form of basic salt, by which the metallic strength of the bath is impaired, and which necessitates the addition of fresh quantities of the double sulphate from time to time. Where a current of only moderate intensity is used, and which is uniformly maintained, these difficulties will be reduced to a minimum, and the solution will maintain itself in good working order for a long time, requiring only the occasional addition of a little sulphuric acid to correct any pronounced alkalinity that may be exhibited when tested as it should be at frequent intervals, with test-paper. As metallic nickel is difficultly soluble, the use of comparatively large anode surfaces is necessary, because the nickel dissolves so slowly that if the anode surface exposed in the depositing vat is not considerably larger than that of the objects on which the deposit is made, the solution will not keep saturated. There is another reason for the use of a comparatively large anode surface, which will appear further on.

From the preceding remarks it will be unnecessary, perhaps, to add that the double sulphate solution commonly used by nickel-platers presents greater difficulties in its employment than the acid solutions of Potts and others.

Again, the strength of the current should be carefully regulated according to the surface of the articles in the bath, as otherwise the work will be apt to "burn;" that is, the metal will be precipitated a dark gray or black deposit, which discolors and renders it useless. This is evidence of a current of too great intensity. To obviate this difficulty, the plan is generally adopted by careful operators of suspending a plate of nickel, presenting considerable surface at both ends of the rod from which the articles are suspended in the bath. By thus diverting the current the "burning" of the work is prevented.

As a general rule, it is well to observe, that, other things being equal, the slower the rate of deposition, the more adherent and tenacious the coating of deposited metal will be. Where the metal deposits too rapidly, the deposit is apt to be brittle, and to exhibit, especially in the case of a heavy coating, a tendency to split and flake. This is due to the liberation of hydrogen at the cathode, and which is occluded by the electro-deposited metal. To obtain satisfactory results, it is important that the articles should be "struck," that is, receive a uniform coating immediately after they are immersed in the bath.

This is an indication that the articles have been properly cleaned, and are in proper condition to receive the deposit, and also that the bath is working properly. After this first layer has been deposited, the subsequent rate of deposition is much slower, for the reason that the deposit of nickel on nickel does not take place as readily as upon a foreign metal, a rule which appears to hold good of all metals.

Nickel solutions are feebler conductors of electricity than those of gold, silver, and copper, which is one of the reasons why its electro-deposition is attended with more difficulties than are experienced with the metals named. On this account, also, it is necessary to employ stronger depositing solutions than those used for gold and silver, and a stronger current. To make up for this want of conductivity it is advantageous to use a much larger anode surface than is customary with other metals, and it is necessary to place an anode on both sides of an article to be plated. The usual arrangement with a large vat is to have two rails of brass the whole length of the vat, resting on the edges of the same, from which two rows of cast or rolled nickel anodes (to which copper wires are soldered) are suspended. Between these outer rods is placed a similar one also running the whole length of the vat, and from this, by means of suitable slinging wires, the articles to be plated are suspended in the bath. The ends of the rails nearest the battery or dynamo are suitably connected therewith in the usual manner. The work thus hangs between the two rows of anodes.

Watt * very properly calls the attention of the operator in this connection to the importance of having the wire supports from which the articles are hung in the depositing vat, of a gauge suited to the character of the work. Small articles will require but a very thin wire, while larger ones will require correspondingly thicker "slinging wires." On the same point he cautions the operator that the difference of conductivity in the metals to be plated is to be considered, "for, whereas, a steel, brass, or copper article would become readily "struck," even if suspended from the conducting rod by a thin wire, articles of lead, Britannia metal, pewter, or even cast iron would not receive the deposit so readily." It is obvious, therefore, that in suspending articles in the plating bath, the operator must be guided in the matter of the thickness of the "slinging wires," by the nature of the articles, as well as by their dimensions.

* Watt, *Electro-Metallurgy* (7th Ed.), p. 104, *et seq.*

It cannot be too strongly impressed on the operator that the attainment of success in nickel plating depends very largely upon the perfect cleansing of the articles before they are immersed in the bath. Important as this operation is in plating with other metals, it is even more so in the case of nickel. Gilding, silvering, bronzing, etc., are usually effected with solutions having a decidedly alkaline character (reference is made here to the double cyanide solutions commonly used) and the presence of minute traces of oxide from careless exposure to the air after cleansing, or of grease from the fingers, etc., on the surface of the articles to be plated, is not necessarily fatal to the success of the work, as the free cyanide always present in those baths, being a solvent of greasy substances, and of metallic oxides, may remove trifling quantities of such impurities. With nickel, however, the case is different. The solutions employed for its deposition are either neutral, or weakly alkaline or acid. Their chemical character is such, therefore, that they can have little or no solvent effect on the grease or oxide left on the articles by careless cleansing, or improper handling or exposure before immersion; and if such articles are plated, the nickel coating at the unclean places will be found to have little or no adhesion to the metal beneath, and will almost certainly flake or strip at these places in the subsequent operation of buffing. Unless the surfaces to be coated are *chemically* clean an adherent deposit of nickel is simply impossible.

On account of the hardness of the deposited metal, nickel-plated articles cannot be burnished. In order, therefore, to obtain upon the finished work that suberb metallic lustre which characterizes this metal, it is necessary to polish the surface of the articles upon the buffing-wheel before immersion in the plating bath, in order that the deposited metal may be as smooth as possible; thus reducing the amount of subsequent buffing, required to finish the plated articles, to a minimum.

The operation of cleansing articles differs somewhat in various establishments; the following methods, however, are those usually followed.

For copper, brass, Britannia-metal, tin, pewter, etc., the articles are first steeped for a few minutes in boiling potash solution to remove greasy matter; they are then removed, dipped for an instant in cyanide of potassium solution of moderate strength, rinsed in water, again rinsed, then thoroughly brushed with the finest pumice powder (precipitated chalk and other fine powders are also used); again rinsed in

water, dipped again for an instant in the cyanide, well rinsed, and then hung at once in the nickel bath. The time of immersion in the boiling potash solution will depend on the strength of the alkali, and the amount of greasy matter present. Tin, Britannia, pewter, however, should be left in it as short a time as possible, as the alkali exerts a solvent action on tin and alloys containing this metal. When rinsed in water after removal from the potash, the water should wet the surface uniformly; should any cloudy patches be visible, these indicate that the grease has not been completely removed, and the article must be immersed again in the boiling potash.

Steel articles are first treated to the potash bath; rinsed in water, scoured with pumice powder (or its equivalent), rinsed, dipped for a moment in dilute hydrochloric acid, again rinsed, and at once hung in the depositing vat.

Cast iron is first placed in the potash bath to remove greasy matter, well rinsed, then allowed to remain for some time in a pickle of dilute sulphuric acid to partially dissolve off and partially soften the scale that covers it, rinsed, then thoroughly brushed with pumice, rinsed, dipped for a moment in dilute hydrochloric acid, again rinsed, and immediately placed in the nickel bath.

Many operators vary the above methods of cleansing somewhat, but they are followed substantially as given, by the majority of nickel-platers. With Britannia-metal, pewter, and other compositions of comparatively low conductive power, it is to be recommended to give them a preliminary coating of copper, for which purpose the cyanide bath is commonly employed. Many operators prefer also to copper articles of iron and steel preparatory to nickel-plating. The advantages secured are a better conducting surface upon which to lay on the nickel, and a more tenacious deposit, having in the case of a heavy coating of nickel less tendency to flake. Where a substantial and durable nickel deposit is required on iron and steel, and especially where the articles are to be exposed to the atmosphere, or will be subject to much handling, a preparatory coating with copper is almost indispensable. In the earlier days of nickel-plating it was the almost universal practice to first copper all iron and steel articles.

The enormous extension of nickel-plating of late years has caused its application to an endless variety of articles of trifling value merely to enhance their beauty, and this, together with the severe competition among those in the business has combined to cause a very general

deterioration in the quality of nickel-plated work. The necessity of doing cheap work is responsible for the fact, therefore, that thousands of articles are turned out of the nickel-plating works with the merest wash of nickel. The want of durability exhibited by these inferior goods has had the consequence that many have formed a low estimate of the utility of nickel as a protective coating for metals, which it is far from deserving.

It is important that the work should be examined very shortly after it has gone into the nickel bath, to observe whether it has been "struck" and its general appearance. Should dark streaks exhibit themselves upon the work, they may indicate either that the current is too intense, or that the work has not been properly cleansed. Such streaks will often be observed, starting from joints, seams, or rivets, where the grease from the buffing-wheel may have secured lodgment, and from which it is difficult to perfectly remove it. In such cases the work must be removed and given another thorough pumice brushing and rinsing, and again immersed in the depositing vat.

As has already been briefly noticed, the hardness of electro-deposited nickel renders it impossible to finish the plated articles by burnishing. It is, therefore, necessary to prepare the surfaces of the articles to receive the nickel deposited before they are plated, in order to reduce the subsequent finishing operations as much as possible. On this account it is customary to polish the surfaces of articles to be plated on buffing wheels. In case the surface is very rough, as is sometimes the case with articles of iron or steel, it may be necessary to grind it smooth upon the emery wheel. The work, when removed from the nickel bath, is dipped for a few moments into boiling water, and then rapidly dried in sawdust. It is now ready to be polished on the buffing wheels when it is finished.

The length of time required to produce a sufficiently heavy deposit of nickel will depend on the strength of the current, the condition of the bath, and the character of the articles. Brass and copper articles usually receive a sufficiently heavy coating in half an hour; for wares on which an extra-heavy coating is desired the time of immersion is extended to an hour or even longer. Iron and steel, Britannia-metal, pewter, etc., require a longer time of immersion than brass or copper, even though given a preparatory coating of copper, because of their comparatively inferior conductibility. A good coating of nickel, prop-

erly laid on, possesses great durability, and with ordinary usage will last for many years.

Old nickel-plated work which it is desired to replate should first be "stripped," as is found necessary with the precious metals. For this purpose a mixture of sulphuric and nitric acids is commonly employed. Watt* recommends the following mixture which will be found very serviceable, viz.: "4 pounds strong sulphuric acid, 1 pound nitric acid, and about 1 pint of water." By volume, these proportions would be approximately: Strong sulphuric acid 2 parts, nitric acid 1 part, water 1 part. The acids should be added to the water under constant stirring. This stripping liquid may be used either cold or slightly warm. It acts promptly, removing a light coating of nickel in less than a minute, and a heavy one in a few minutes. To avoid contaminating the solution as little as possible with the metal of the wares, the operation should be closely watched and the articles removed from the acid just as soon as the nickel has been dissolved. The preparation of the stripped articles for re-nickeling should be the same as for new work. Articles may be stripped in the nickel bath by the ordinary artifice of connecting them as anodes, but the practice is reprehensible, as the purity of the bath will thereby become impaired by the solution of the metals composing the wares. Where the current is used for the purpose, therefore, a separate solution should be used, and for this purpose Watt's suggestion to use as a stripping solution dilute sulphuric acid which will dissolve nickel readily without appreciably affecting brass, may be recommended. Under all circumstances, however, the articles should be looked at from time to time, and removed as soon as they are free from nickel. It is important, however, that the old nickel be thoroughly cleaned off, to prevent the peeling of the subsequent nickel deposit.

PLATING WITH NICKEL BY IMMERSION.

Stolba† describes the following simple process for nickel-plating without the battery, which may be usefully applied in the case of small objects. He dilutes a concentrated solution of chloride of zinc with twice its volume of water. This mixture he boils in a copper vessel, adding a few drops of muriatic acid should there appear a precipitate

* Watt, *Electro-Metallurgy* (7th Ed.), 114, *et seq.*
† *Journal Chemical Society*, xl, 463.

of basic chloride of zinc. He thereupon adds a small quantity of powdered zinc. This addition causes a deposit of zinc upon the vessel. Thereupon sufficient chloride or sulphate of nickel is added to the bath to give it a distinctly green color, and the previously cleansed articles are then immersed in the liquid in contact with zinc, and allowed to remain there for about fifteen minutes, the temperature being maintained at boiling during the operation. If the coating is found to be insufficient the articles are again immersed until a deposit of sufficient thickness is obtained. In this way, he claims to be able to coat satisfactorily, articles of zinc, cast and wrought-iron, steel, and copper.

By an analogous process described by C. Mène,* it is affirmed that metallic articles may be plated with nickel by immersing them in contact with zinc, in a boiling neutral solution of chloride of zinc, in which is contained fragments or a plate of nickel. Should the solution be acid the plating, it is asserted, will be dull. By this procedure the author claims to be able to coat articles of iron, steel, copper, brass, zinc and lead.

Where electrotypes of type or engravings are to be printed with colored inks that are disposed to become chemically affected by contact with the usual copper surface (as for example vermilion, which becomes brownish) it is customary to give the copper electrotype a thin coating of nickel in the usual manner. This nickel renders the electrotype proof against the above-named difficulty that printers experience with electrotypes not so protected.

By methods and solutions analogous to those described for nickel, electro-deposits of cobalt may be obtained. The electro-deposits of this metal equal, if indeed they do not surpass, those of nickel, in whiteness and brilliancy of lustre. The costliness of the metal, however, prevents its use for this purpose.

Black Phosphorus.—Many chemists dispute the existence of black phosphorus, regarding it as a mixture of ordinary phosphorus with traces of a metallic phosphorus which gives the color. Without denying that this may often be the case, Thenard reports an experiment which leads him to doubt that it is always so.—*Comptes Rendus*, Aug. 28, 1882. C.

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* *Chemical News*, xxv, 214.

Density of Liquid Oxygen.—M. Offret deduced, from the experiments of Pictet, the probable value of ·84 for the density of liquid oxygen. This result is not trustworthy, since it depends upon an estimate of the quantity of oxygen which still remained in a gaseous state in Pictet's apparatus. This quantity cannot be calculated, even approximately, because it requires an exact knowledge of the laws which replace the laws of Mariotte and Gay-Lussac, and the knowledge of the distribution of temperature in the gaseous mass which is found in the unchilled portion of the tube. Wroblewski finds, by an indirect method, which is described in the proceedings of the French Academy, ·895 as the most probable value of the density. Dumas considers this result as a confirmation of the views which he had announced in comparing oxygen to sulphur.—*Comptes Rendus*, July 16, 1883. C.

Critical Temperature and Pressure of Oxygen.—S. Wroblewski compresses oxygen in a vertical glass tube, bent in its upper portion so as to be plunged into liquid ethylene, and produces a vacuum above the ethylene by the aid of a powerful pump. The portion which is plunged into the ethylene has the temperature of the liquid, but in the other portion the temperature increases, after a regular law, with distance from the surface of the liquid ethylene. The temperature of the ethylene depending upon the degree of the vacuum, the pressure, which is observed when the first traces of liquid oxygen appear at the bottom of the curved and cooled portion of the tube, represents the pressure of liquefaction for the corresponding temperature. If a large quantity of gaseous oxygen is used, and the quantity of liquid oxygen increased by diminishing the volume of the unliquefied gas, it is found that in proportion as the column of liquid oxygen surpasses the level of the ethylene the pressure increases; the liquid oxygen comes into the part of the tube where the temperature is greater than that of the liquid ethylene and the observed pressure corresponds to the temperature of the tube at the place of the oxygen meniscus. If the experiment is continued, so as to increase the height of the oxygen column, a pressure is finally reached at which the meniscus completely disappears. Its place can be merely suspected from the difference of the refrangibility of the light above and below. A diminution of pressure makes the meniscus again visible. This phenomenon always reappears at the same pressure of about 50 atmos-

pheres. A similar phenomenon can be produced with carbonic acid, and by experiments in liquefying both these gases Wroblewski has arrived at —113°C. (—171·4°F.) as a first approximation of the critical temperature of oxygen. By combining this result with those which he published in a previous note (*Comptes Rendus*, xcvi, 1142), we may obtain an idea of the curve of liquefaction.—*Comptes Rendus*, July 30, 1883. C.

Analogy between Allotropic Phosphorus and Arsenic.— R. Engel has shown that when arsenic is isolated from one of its compounds, at a temperature below 300° (508°F.), it has an allotropic state which he calls amorphous. The amorphous arsenic differs from crystallized arsenic, both in density and in its point of sublimation. In these two respects amorphous arsenic approximates to white phosphorus, and crystallized arsenic to red phosphorus, the crystals being isomorphs. Both white phosphorus and amorphic arsenic are sublimed at a temperature below that of transformation. Neither red phosphorus nor crystallized arsenic can be sublimed at that temperature. The vapor of red phosphorus gives white phosphorus when it is cooled below the temperature of transformation, the vapor of crystallized arsenic gives amorphic arsenic under like circumstances.—*Comptes Rendus*, April 30, 1883. C.

Mechanical Glass Blowing.—A small apparatus was invented, in 1824, by a workman of Baccarat, to supplement the ordinary process of glass blowing. It is known as the Robinet piston, and renders useful service, but the small quantity of air which it is able to compress makes it available only for small pieces. Messrs. Appert have devised a process, in their factory at Clichy, in which they use air stored under great pressure, so as to dispense altogether with the necessity of blowing by the mouth. Glass-blowers are peculiarly susceptible to various disorders, such as diseases of the lips and cheeks, and predisposition to tumors and rupture. These affections are the more serious, because boys are often employed when the system is weakened by rapid growth. The high temperature and dry atmosphere increase the unfavorable hygienic conditions. The new process entirely suppresses mouth blowing by boys and, with rare exceptions, by adults also. The manufacture of glassware is thus ameliorated by rapidity of execution, as well as by the perfection and the large size of the pieces which are produced.—*Comptes Rendus*, June 4, 1883. C.

Modification of the Law of Isomorphism.—According to Mitscherlich, two bodies are called isomorphs when they have an analogous chemical composition, present the same crystalline form, and can crystallize together in the same crystals. Scheibler remarked the isomorphism of most of the metatungstates, although they do not contain the same quantity of water of crystallization. Marignac, in his magnificent study of silicotungstates, has shown that there is a perfect isomorphism of the acid silicotungstates of baryta and of lime, and of rhombohedric silicotungstic acid. Moreover, a small quantity of potash can replace the water in the acid, without altering the crystalline form. The same author regards certain double fluorides and oxyfluorides as isomorphs. Klein has described various isomorphs, and he proposes to adopt Marignac's modification of the law of isomorphism, viz., isomorphs either have a like chemical composition, or they have a composition which is approximately similar, while enclosing a group of common elements, or of functions chemically identical, which form much the greatest part of the weight.—*Comptes Rendus*, Oct. 30, 1882.

Origin and Periodicity of Comets.—Charles V. Zenger has examined Mädler's catalogue of cometary orbits, covering a period of 23 centuries, and finds indications of a thirteen-days' period, but the old observations are neither rigorous nor numerous enough to give the date of perihelion with precision. He has, therefore, supplemented this study with modern observations, which are sufficiently precise to furnish the date, within a day, for all the comets which have been observed between 1877 and 1882. On dividing the intervals between their successive perihelia by whole numbers, he finds unit periods ranging between 10·83 and 14·25 days, the mean value being 12·56 days, which is almost precisely that of a solar half rotation. He concludes, therefore, that the origin of comets must be intimately connected with the rotation of the sun. Supposing that there are two points upon the sun's surface, differing in longitude by about 180°, as is the case in the two centres of cyclonic disturbance on the earth's surface, the formation of comets may be explained by enormous explosions, driving the materials of the protuberances to distances of hundreds of thousands of kilometres.—*Comptes Rendus*, Jan. 8, 1883. C.

Vegetable Acclimation.—Baron de Brandis gives some curious information about the changes in the time of flowering of the acacia

dealbata, which was imported from Australia into India. For fifteen years after its introduction it blossomed in October. In 1860 the flowers appeared in September; ten years later in August; in 1878, during the month of July; in 1882, in June. It therefore required thirty-five years to adapt itself to the climate of India, and to modify its vegetation so that the phases would agree with the seasons of its new home.—*Les Mondes*, Aug. 4, 1883. C.

Metallization of Wood.—Rubennick's process steeps the wood in a bath of caustic alkali, for two or three days, according to its degree of permeability, at a temperature between 164° and 197° F. The wood is then placed in a second bath of hydro-sulphate of calcium, to which is added, after 24 or 36 hours, a concentrated solution of sulphur. After 48 hours the wood is immersed in a third bath of acetate of lead, at a temperature between 95° and 122° F., where it remains from 30 to 50 hours. After a complete drying, the wood thus treated is susceptible of a very fine polish, especially if its surface is rubbed with a piece of lead, tin, or zinc, and finally finished with a burnisher of glass or porcelain. It then looks like a metallic mirror, and is completely sheltered from all the deteriorating effects of moisture.—*Les Mondes*, July 28, 1883. C.

Oxycitric Acid.—Edmund Lippmann, a German chemist, has discovered in the incrustations which are deposited in the evaporators during the manufacture of beet sugar, a crystallizable body which is a very energetic tribasic acid. He regards it as identical with the product which has been described by Parvoleck, under the name of oxycitric acid.—*Les Mondes*, July 28, 1883. C.

Nervous and Intellectual Contagion.—The contagion of nervous, intellectual, and moral phenomena, is attracting the attention of French physicians. It comprises nervous tics, epileptiform disorders, insanity and other mental affections, the inclination to suicide, crime, etc. M. Rambosson, a laureate of the French Institute has published an octavo volume of four hundred pages upon the subject, which was presented to the Academy of Medicine by Baron Larry, in very complimentary terms.—*Les Mondes*, July 7, 1883. C.

Periodicity of Comets.—Prof. Zenger has examined the dates of the perihelia of the comets which have been observed since 1877,

and finds that their successive intervals are multiples of 12·56 days, or one half rotation of the sun. He deduces from this fact inferences which will be of great consequence if they are well sustained. I. The comets are produced by violent explosions, which throw the gases to hundreds of thousands of kilometres from the sun. When this projected matter encounters a cosmic mass the latter will form the nucleus of the comet, and the gaseous material will be the tail. II. The duration of the cometary revolution will be a multiple of the solar half rotation. If S is the solar rotation, and T the cometary revolution, we have

$$T = \frac{nS}{2}.$$

The value of n for Encke's comet is 95; for Brorsen's, 159; for Tempel's, 173.—*Les Mondes*, June 15, 1883. C.

Phosphoric Glass.—The phosphoric glass, which Sidot described to the French Academy, resembles ordinary glass in density and refracting power, but it is only slightly affected, if at all, by fluorhydric acid. Encouraged by the interest which was manifested in the Academy, he has continued his experiments, and has submitted a number of retorts, tubes, etc., to the Academy for examination.—*Comptes Rendus.*, June 11, 1883. C.

Choice of a Prime Meridian.—The Minister of Public Instruction submitted to the French Academy the proposal of the United States government for an international congress, to select a universal prime meridian and to agree upon a common standard of time. M. Faye, on behalf of the committee to whom the subject was intrusted, cordially recommended the acceptance of the proposal and the appointment of scientific representatives of the various interests, of astronomy, navigation, telegraphy, geography, and terrestrial physics. M. de Chancourtois proposed a decimal division of the day and of the circumference of the globe, somewhat similar to that which was adopted after the first French Revolution, so as not only to adopt a universal hour but also a universal scale for the absolute measure of time. He thought that the prime meridian should either be that of Ptolemy or that which passes through Behring's straits, both of which would be free from any competition of national pride, since they traverse no habitable lands.—*Comptes Rendus*, Jan. 15, 1883. C.

Principle of the Telephone.—Prof. Govi has contrived an experiment which he calls a demonstration of the principle of the telephone. He takes two tuning forks, which he puts in close proximity to two magnets, each of which is surrounded by a copper wire which serves to connect them together. On sounding one of the tuning forks with a bow, the vibrations are transmitted by the wire and are reproduced in the other fork.—*Les Mondes*, March 17, 1883. C.

CORRESPONDENCE.

To the Committee on Publication.

In *Science* of January 25th last I find the following, in a communication by Professor Eddy, referring to the Second Law of Thermodynamics, as published in your JOURNAL: "In my reply in the same Journal for June, 1883, I showed the fallacy of his objection. So far as I know, Professor Wood has taken no notice of that reply, and now completely ignores it."

Having been called to an account in this public manner, I may be pardoned, at this late day, for saying that I intentionally ignored it, for it contained no reply to my argument.

Yours truly,

DE VOLSON WOOD.

To the Committee on Publication:

GENTLEMEN:—In the JOURNAL OF THE FRANKLIN INSTITUTE for January, 1884, I have noticed a criticism by Mr. Hugo Bilgram, on my proposition, published in the December issue of 1883, page 471, and it seems to me that your correspondent, in quoting from Dr. Grashof, that a level surface is such "that the resulting force of all attractions is in all points normal to the same," should have observed that this same force must necessarily act in a normal direction upon the contiguous level surface, for otherwise there would be a tangential component disturbing the supposed equilibrium of the liquid mass.

This justifies my tacit assumption that the inner surface of the uniform and exceedingly thin stratum of liquid which is in my demonstration supposed to become like a shell, is a surface of level, and consequently my conclusion is unavoidable. L. D'AURIA.

Philadelphia, February 20, 1884.

List of Books added to the Library during October, November and December, 1883.

Academie des Sciences. Tables Générales des Comptes Rendus. Tomes. 1–61, in 2 Vols. Paris, 1853 and 1870.

Academie Royale des Sciences, Lettres et Beaux-arts de Belgique. Tables Générales des Bulletins. 2e. Serie. Tomes 21–50. 1867–1880. Bruxelles, 1883. From the Academy.

Adams, H. Notes in Mechanical Engineering. London. Spon, 1883.

Adjutant General of Pennsylvania. Annual Report. 1866. Harrisburg.

Allentown, Pennsylvania. Annual Reports of the Water Commissioners for 1876, 1877, 1879–1882. From the Commissioners.

American Academy of Arts and Sciences. Proceedings. Vol. 10. 1882–1883. Boston. From the Academy.

American Agriculturist. Vols. 1, 2, 3, 5–10, inclusive. New York.

American Association for the Advancement of Science. Reports of Proceedings of 7th, 13th to 20th, and 27th to 31st Meetings. From the Association.

American Ephemeris and Nautical Almanac, for 1884 to 1886. Washington. From the Superintendent.

American Exchange and Review. Vols. 1 to 4 and 6 and 7. From John A. Fowler. Editor. Philadelphia.

American Geographical and Statistical Society. Journal. Vol. 1. New York.

American Geographical Society. New York. Journal. Vols. 3 to 13. 1870–1881. From the Society.

American Iron and Steel Association. Bulletin No. 27. August 24, 1881. Vol. 15. From the Secretary.

American Journal of Microscopy. January, March, April and June, 1881. From Dr. W. H. Wahl.

American Machinist. Nos. 4, 6, 8, 10 and 12 of Vol. 1, 1878. New York. From the Publisher.

American Monthly Microscopical Journal. June and August, 1881. From Dr. W. H. Wahl.

American Pharmaceutical Association. Proceedings. 1871 to 1881. Philadelphia. From J. M. Maisch. Editor.

American Philosophical Society. Catalogue of the Library. Part I. 1863. Philadelphia. From the Society.

American Philosophical Society. Transactions. New Series. Part 1. Vol. 16. Philadelphia, 1883.

American Printer: a Manual of Typography. Philadelphia, 1883. From MacKellar, Smiths and Jordan, Publishers.

American Water Works Association. Constitution and By-laws, with Proceedings of 1st and 2d Annual Sessions. 1881 and 1882. From J. H. Decker, Secretary.

American Water Works Association. Annual Reports. 1st to 3d. 1881–83. From J. G. Briggs, Terre Haute, Indiana.

Army Register. Official. January, 1876. Washington.

Ashburner, Chas. A. Anthracite Coal Beds of Pennsylvania. Philadelphia, 1882. From the Author.

Ashburner, Chas. A. New Method for Estimating the Contents of Highly Plicated Coal Beds as applied to the Anthracite Fields of Pennsylvania. From the Author.

Ashburner, Chas. A. New Method of Mapping the Anthracite Coal Fields of Pennsylvania. 1881. From the Author.

Astronomical and Meteorological Observations made in 1879. Washington, 1883. From the United States Naval Observatory.

Astronomical Observations made under the Direction of M. F. Maury, 1845. Washington, 1851. From the Nautical Almanac Office.

Atlantic and St. Lawrence Railroad Company. Annual Reports, 1844–1883. Portland. From the Company.

Auditor-General's Report on Railroads of Pennsylvania. 1863, 1864 and 1866. Harrisburg.

Bailey, R. A. United States National Loans, 1776–1880. Washington, 1882. From the Treasury Department.

Baltimore and Ohio Railroad Company. Annual Reports, 1859–1882. From the Secretary.

Baltimore, Md. Annual Report of the Water Department to the Mayor and Council for 1882.
From B. K. Martin, Chief Engineer.

Bangor and Piscataquis Railroad Company. Reports of the Directors. 1876–1882. From the Company.

Banker's Magazine. April, 1867; August, 1868. New York.
From I. S. Homans.

Banks and Saving Institutions of Pennsylvania. Reports for 1880. Harrisburg. From Hon. G. W. Hall, House of Representatives.

Bay City, Mich. Annual Reports of the Superintendent of Water Works, 1875, 1877–1882. From the Superintendent.

Berthelot, M. P. E. Explosive Materials. New York. Van Nostrand. 1883. From the Publisher.

Binghampton. Annual Reports of the Board of Water Commissioners for 1876, 1878–1880 and 1882. From the Commissioners.

Blair, H. Lectures on Rhetoric and Belles Lettres. From B. B. McKinley.

Blake Manufacturing Company. Illustrated Catalogue of Improved Steam Pumping Machinery. New York. From the Company.

Blodget, L. Census of Manufacturers of Philadelphia, 1883. From Charles Bullock.

Board of Agriculture of Pennsylvania. Annual Report for 1882. Harrisburg, 1883. From Hon. G. W. Hall, House of Representatives.

Board of Education of First School District. Philadelphia. Annual Reports. 1821–1883. From the Board.

Board of Health. Philadelphia. Annual Reports for 1860 and 1877. From His Honor the Mayor.

Board of Public Education. Sixty-fourth Annual Report. Philadelphia, 1883. From the Board.

Board of Public Works. Chicago, Ill. Tenth Annual Report. 1870–1871. From the Board.

Board of Supervising Inspectors of Steam Vessels. Proceedings of the 30th Annual Meeting. 1882. Washington. From the Supervising Inspector General.

Board of Trade of Philadelphia. Annual Reports. 1865–1882. From G. L. Buzby, Secretary.

Boston, Concord and Montreal Railroad. Twenty-seventh to Thirty-seventh Annual Reports of the Directors. 1873–1883. From the Company.

Boston Journal of Chemistry. Missing Nos. required to complete Serial. Boston.

Boston, Mass. Annual Reports of the Cochituate Water Board to City Council for 1855, 1857, 1858, 1860–1869 and 1871, 1872 and 1874–1876.

Annual Reports of the Water Board for 1878 to 1883.

Description of the Water Works. Chicago, 1878.

Report of the Medical Commission upon the Sanitary Qualities of Sudbury, Mystic, Shawshine, and Charles River Waters. Boston, 1874.

Report of the Cochituate Water Board. October 31, 1873. Boston, 1874.

Report of Joint Standing Committee on Water, with Report of City Engineer. Boston, 1874.

From A. Febs, Chief Assistant City Engineer.

Special Report of the Water Board. Sept. 6, 1883.

Boston Public Library. Annual Reports of the Trustees. 1854–1877. Boston. From the Library.

Brevêts d'Inventions. Tomes 104 et 105. Paris, 1883.
From Ministre du Commerce.

Brewer, Distiller and Wine Manufacturer. Philadelphia: P. Blakiston, Son & Co. 1883. From the Publisher.

Bridgeport Hydraulic Company. Reports of the Superintendent to Directors. 1876, 1879, 1881 and 1883.
From the Superintendent.

Briggs, R. Steam Heating. New York. Van Nostrand. 1883.
From the Publisher.

Brooklyn Library. Annual Reports of the Board of Directors. Brooklyn, N. Y., 1865–1882. From the Librarian.

Brown, J. C. French Forest Ordinance of 1689. Edinburgh: Oliver & Boyd. 1883. From the Publishers.

Brown, Thos. Lectures on the Philosophy of the Human Mind. 2 Vols. Boston, 1826. From B. B. McKinley.

Browne, W. R. Student's Mechanics. London: Griffin & Co., 1883.

Buck, Rev. C. Theological Dictionary. Philadelphia, 1838.
From B. B. McKinley.

Buffalo, N. Y. Annual Reports of the City Water Works, 1872–1877 and 1879–1882. From the Water Commissioners.

Builder. 1843–1844 and 1877. London, 1844 and 1877.

Bureau of Education. Department of Interior. U. S. Annual Reports of Commissioner of Education, for 1868 and 1881. Washington.

Answers to Inquiries. By C. Warren. Washington, 1883.

Circulars of Information. July and August, 1870; November and December, 1871; April and November, 1872; January, February, March, June and Nos. 1 and 3, 1874; Nos. 3 and 4, 1879; No. 3, 1883. Washington. From the Bureau.

(To be continued.)

Book Notices.

KINEMATICS; OR, MECHANICAL MOVEMENTS. MacCord. 336 pages. 8vo. New York: John Wiley & Sons, 1883.

Unless it is the intention of the author to make the present volume only one of a very large number of volumes, it would seem much better to call it what it is, a treatise on gearing.

On opening the book one is at once pleasantly impressed by the great neatness and number of the drawings. Moreover, these drawings are not slavish copies from unacknowledged sources, such as we too often see, but are many of them original, and where they are not new, are great improvements upon the rude outlines given by Willis and Rankine. It is indeed impossible to have too many or too good drawings for such a work as this.

There is another point about the book worth noting. Internal evidence shows in every chapter that a vast amount of work not shown to the careless reader has been done. The minutest details have evidently been given much thought, and possibly, experimental proof. There has been no careless generalizing after the manner of Rankine. Indeed, we might say, that there is no generalizing at all in the book.

This is a decided advantage for the mechanic who only uses the book for the special mechanism of which he desires to avail himself; it may be regarded as a deficiency where we use it as a text-book for students. This deficiency can well be excused by any person who has had to work up a subject thoroughly elsewhere in order to grasp the meaning of Rankine's vague and vast generalizations, or who has found himself left at the gateway of practical application by Willis, with perhaps the severest work yet to be done before he realizes what he desires to accomplish.

We fear that too much credit is given to those who in the past have recorded a new idea and have left others to determine limitations and exceptions which will render it useful or correct in its application. The *really* new ideas are few, and most of our great authorities are men characterized by a facility of expression which has enabled them to collate and arrange what is floating in the intellectual atmosphere of of their times; they have been bookkeepers, rather than active, busy mechanics or men of original thought, and seem rather to have great

power of absorption and assimilation than of original thought. Few, indeed, are the really original thinkers.

Prof. MacCord deserves credit for independence in having subjected authority to careful scrutiny before accepting it. His adherence to graphical methods and to simple geometrical and algebraic methods will be a great relief to the busy man of the shop, yet it is a serious defect in the classroom.

It would have been better, and have given students a broader comprehension had Prof. MacCord shown, as can be shown, that equations can be established, from the consideration of two axes in space joined by a common normal, which will make one group of cylinder, hyperboloid and cone, and admit of one general graphical solution if necessary.

It would have been easy to call the attention of students to the fact that the family of hyperboloidal gears are characterized by teeth whose directrices lie parallel to, or are coincident with, the generatrix of their pitch surfaces and are straight, and that spiral gears of all kinds differ only in that the directrix of the tooth forms an angle with the generatrix of the surface.

The treatment of cutters given is elaborate and does give a clear idea of what cutters are and what they are intended to produce.

Pratt & Whitney receive a puff, and Brown & Sharpe a criticism, which should not appear in a scientific work. Really Saxton deserves the credit of having devised what seems to have been awarded to Pratt & Whitney and Brown & Sharpe.

Every mechanic knows that while probabilities of error exist in Brown & Sharpe's method of transference of shape of teeth to throat tools, still, milling the edge of a cutter leaves it without clearance in the case of Pratt & Whitney, and this latter point is not mentioned.

One ought to be fair if one assumes the role of umpire in business matters.

Pages 186 to 195 are devoted to the determination of a series of cutters by graphical methods. The condition that the addendum to a cut tooth is one diametral pitch would render this solution more exact and brief analytically. For instance, if we call a the angle between a line drawn through the centres of pitch and describing circles and a line drawn from the centre of the describing circle to the outside corner of the epicycloidal tooth, we have the following equations for computing

accurately the thickness of a cutter for any pitch describing circle and number of teeth.

$$\text{Cos. } a = 1 - \frac{8(n+1)}{d(2n+d)}$$

in which $n =$ number of teeth in wheel desired and $d =$ number of teeth in straight flank pinion.

The thickness of cutter T then is

$$T = \frac{n+2}{p} \text{ sin. } \left[\frac{90^\circ}{n} + \frac{d}{2n} a - \text{sin.}^{-1} \left(\frac{d}{2(n+2)} \text{ sin. } a \right) \right]$$

in which $\frac{1}{p} =$ the diametral pitch.

If we assume this to be 1, and compute the series, we have only to divide by the number of teeth per inch to obtain the exact thickness of cutter for any pitch and for any system whatever that we may have fixed upon.

There is an unpleasant affectation of familiarity of speech in parts of the book that could well be spared. *Vide* p. 220, for instance.

"The fallacy above mentioned, if crushed by theory, is pulverized by practice."

The great excellence of this work lies in its drawings and the microscopic thoroughness of its scrutiny of details.

It is far more valuable to the practitioner than any yet written in English and is well worth reading by every student of mechanism.

The faults are trifling and its merits many.

W. D. M.

Electricity, Magnetism and Electric Telegraphy; a Practical Guide and Handbook of General Information for Electrical Students, Operators and Inspectors. By Thomas D. Lockwood. New York: D. Van Nostrand, publisher.

This is a volume of 377 pages, containing a large amount of practical information clearly and concisely presented. About 150 pages are devoted to practical telegraphy and telephony, and the chapter on electrical measurements is also written with special reference to its application to telegraphy. The information is given in the form of question and answer, and the questions are just such as would be asked by an unscientific person practically engaged in the utilization of the mysterious forces of electricity and magnetism to give him a general

knowledge of the subject. It is what it professes to be, a handbook, and is a good one. There is a noticeable absence of anything like "padding," and there is a freshness in the method of presenting the underlying principles of the science which makes the volume a very attractive one. E. A. S.

SATURATED STEAM THE MOTIVE POWER IN VOLCANOES AND EARTHQUAKES; Great Importance of Electricity. By R. E. Peacock, C. E. F. G. S. Second edition, improved. London: E. & F. N. Spon, 16 Charing Cross; New York: 44 Murray street. 1882. Pp. 198.

The improvements appear to consist chiefly in a supplement of addenda and errata, in number about thirty, and in space fifty pages. The author refers to and copies a review of his first edition, which he states appeared in the January number for 1883 of "that first-class scientific publication, the *Philosophical Magazine*," with which he expresses himself "on the whole gratified," and which says: "Evidence is quoted from various authorities to the effect that (1) free hydrogen has been detected in the flames issuing from certain volcanoes; (2) the temperature of the combustion of oxygen with hydrogen is 14·541°F.; (3) clouds of steam are frequently ejected from volcanoes; (4) the pressure of saturated steam at 14·541°F. is about one million tons per square inch." Hence the conclusion that "there is no other terrestrial force at all approaching to saturated steam in power and magnitude," and the question (about volcanic eruptions and earthquakes). Will any man venture to deny that saturated steam was the active agent on these occasions? answered, further on, thus: "This steam *necessarily* causes earthquakes and volcanoes, for how is it possible that so very vast a power can remain idle?"

After referring to the author's experience on a runaway horse, which he cites in support of his theory, the reviewer proceeds: "In other cases, statements of fact are generally freely supported by quotations from authority; the author even thinks it as well 'to prove by a quotation from 'Chemistry' that, since air and water were present in the volcano of Java, oxygen and hydrogen were necessarily present also.'"

The author stands by the propriety of this quotation, since he says, in a foot-note: "It is not quite every reader who knows what gases water is composed of. Hence the reference to 'Chemistry.'"

The passage in question may be presented as a specimen of the general style of the work. "We will now prove by a quotation from 'Chemistry' that, since both air and water were present in the volcano of Java, oxygen and hydrogen were necessarily present also. For these are constituents of air and water. Moreover, we cannot doubt that electricity was present also to decompose them into their constituent elements. For it is notorious that electricity has often been seen active in volcanoes."

The review concludes: "The style is not always clear."

The special point sought to be enforced in this edition is that the moving force is "saturated electric steam," as to which the author specially expresses himself in a postscript, on page 184, though in what manner the steam becomes electric he is not at all clear; and, though he speaks frequently of electricity and of electric steam, it would evidently give him much trouble to formulate his views upon the subject in accordance with any accepted theory.

The author has industriously compiled a disjointed mass of information upon the subject of earthquakes and volcanoes, but it is difficult to trace his deductions from them; that steam, "electric" or other, is sufficient in force to effect a volcanic explosion, or an earthquake, is plain, without argument; that it is the cause of them, and especially that "electric" steam is the moving agent, is not demonstrated by his book. G. M. E.

ELECTRICITY IN THEORY AND PRACTICE; or, the Elements of Electrical Engineering. By Lieut. Bradley A. Fiske, U. S. N. New York: D. Van Nostrand. Philadelphia: H. Carey Baird & Co.

"The design of this book is to form a bridge between works written on the theory of electricity and works treating of the practical applications;" or more particularly to "explain the theory of the practical applications." The range of subjects treated are Magnetism, Frictional Electricity, Work and Potential, Voltaic Batteries, Laws of Currents, Secondary or Storage Batteries, Thermo-Electric Batteries, Electro-Magnetism, Induction Currents, Electrical Measurements, Telegraphy, The Telephone, The Electric Light, Electric Machines, Electro-Motors. Electrical Distribution of Power Meters, and Electric Railways.

Those parts of the book devoted to descriptions of applications particularly deserve praise for the elegant clearness and neatness of treatment. There is absence of prosy and muddled descriptions, while

salient points are presented with much vigor. Indeed, the author must be complimented upon the general clearness of his style in presenting the elementary features of Electrical Engineering. The happy omission of the unnecessary, inclines us to overlook the omission of several points one would like to see treated in a work of this character. We may, however, suggest that the actual "theory" of the book might with advantage to many readers have been carried further. We should perhaps have had a fuller explanation of the methods of measurement as applied to Magnetism, and at least a reference to forms of Electric Induction Machines later than the Holtz. The description of Thermo-Electric Batteries would not lose by mentioning, along with the many of perhaps less importance, those of the Clamond and other useful types. Then the chapter on Practical Measuring Instruments might without detriment have included descriptions of Sir Wm. Thomson's Graded Galvanometers and an inkling of the theory of their construction.

As the work stands it is useful and valuable, and will no doubt find many pleased and profited readers. M. B. S.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, February* 20, 1884.]

HALL OF THE INSTITUTE, Feb. 20, 1884.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham in the chair. There were present 198 members and 19 visitors. The minutes of the January meeting were read and approved. The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, Feb. 13th, 11 persons had been elected to membership.

Mr. S. Lloyd Wiegand presented a further communication, respecting the use of cast iron in steam boilers, illustrating the same by the bursting by hydrostatic pressure of a model of the exploded "Gaffney" steam boiler. The paper was discussed by Messrs. J. W. Nystrom and the author, and will appear in the JOURNAL.

The Secretary's report included remarks on the Tunnel under the Mersey, the state of the Bessemer Steel Industry in the United States, the insufficiency of Life Saving Appliances on Shipboard, the Cause of the Red Sunsets, and a description of several mechanical inventions,

viz.: the Fulton Steel Pulley, shown on behalf of the Indianapolis Machine and Bolt Works. It is claimed for this pulley that it combines strength and lightness to an unusual degree. It consists of three parts—the rim, the disk and the hub. The rim and disk are of steel, and the hub of malleable iron, a special feature of the invention residing in the corrugation of the steel disk, which is affirmed to add greatly to the strength of the pulley. These corrugations are done in a press, in which the hot steel sheet is placed for the purpose. The Metzler & Burrell Improved Railway Signal Lantern, for use by trainmen, gatemen, etc., has two globes, of different colors, joined together at the centre by bayonet locks and catch. The handle passes through the centre of the lantern, and is attached firmly to the lamp, forming an axis upon which the lantern may revolve. Only the upper half of the lantern is illuminated, the lower half being darkened by the body of the lamp. The handle catches to the rim of the half that is uppermost. Thus, if a white or clear light is showing, and it is necessary that a signal of danger, or red light, be instantly given, a revolution of the lantern (which can be made in less than one second) gives the red light, or danger signal.

In addition there were shown and described an improved fire escape invented by Mr. John Harper, of Duncannon, Pa.; the Gardner & Woodbridge Threading Tool, made by the Hartford Tool Company; an improved door knob, dispensing with the side or set screw, made by the Yale and Towne Manufacturing Company, of Stamford, Conn., and an improvement in car-couplers, invention of Aaron Park, of Ottumwa, Iowa.

Mr. David Cooper exhibited a fine suite of specimens of Direct Life-size Camera Portraits, illustrating the progress lately made in dry-plate photography. These pictures were taken with dry plates prepared by the Eastwick Dry Plate Company, of New York.

Mr. Washington Jones, seconded by Mr. G. M. Eldridge, offered the following preamble and resolutions, which were adopted:

WHEREAS, The American Society of Civil Engineers, and the American Society of Mechanical Engineers are urging upon Congress the importance to the Mechanic Arts of a thorough investigation of the strength and other qualities of materials used for structural purposes; and

WHEREAS, The Franklin Institute, in the year 1836-1837, by its Committee on the Explosions of Steam Boilers, conducted a series of experiments made at the request of the Treasury Department of the United

States, and submitted a valuable report upon its "examination of the strength of the materials employed in the construction of steam boilers"* made with such appliances as were then obtainable ; and

WHEREAS, The Franklin Institute, believing that a continuance of such investigations, with the improved means of the present time, will prove to be of much benefit to the large and diversified industries of the country ; therefore be it

Resolved, That the petition of the Franklin Institute be presented to Congress, respectfully asking for the "appointment of a Committee of Experts for the testing of iron, steel and other building material," with a suitable appropriation for its expenses.

Mr. Samuel Sartain offered an amendment to the by-laws, *i. e.*, to add, at the close of Article III, Section 3, the following words: "*Provided*, that no payment less than the full contribution for one year shall entitle the member to admission to the Exhibitions." It was ordered that the proposed amendment take the usual course prescribed by Article XVI.

The following were named by the President to constitute the Standing Committees of the Institute for the year 1884:

On the Library.—Andrew Blair, Charles Bullock, J. Howard Gibson, Fred'k Graff, Wm. D. Marks, S. H. Needles, Isaac Norris, Jr., Chas. E. Ronaldson, Lewis S. Ware, Jos. M. Wilson.

On Minerals.—Clarence S. Bement, Persifor Frazer, F. A. Genth, Edwin J. Houston, George A. Koenig, Otto Lüthy, E. F. Moody, H. Pemberton, Jr., Theo. D. Rand, Wm. H. Wahl.

On Models.—Edward Brown, H. L. Butler, C. Chabot, L. L. Cheney, N. H. Edgerton, John Goehring, Morris L. Orum, Chas. J. Swain, John J. Weaver, S. Lloyd Wiegand.

On Arts and Manufactures.—J. Sellers Bancroft, Geo. Burnham, Cyrus Chambers, Jr., Geo. V. Cresson, Wm. Helme, Wm. B. Le Van, Alfred Mellor, J. W. Nystrom, Henry Pemberton, John J. Weaver.

On Meteorology.—David Brooks, J. B. Burleigh, Wm. A. Cheyney, J. A. Kirkpatrick, T. B. Maury, Isaac Norris, Jr., Hector Orr, Alex. Purves, M. B. Snyder, Wm. H. Wahl.

On Meetings.—Charles H. Banes, A. B. Burk, G. Morgan Eldridge, Fred'k Graff, Washington Jones, J. E. Mitchell, H. W. Sellers, M. B. Snyder, Wm. H. Thorne, John J. Weaver.

Adjourned. WM. H. WAHL, *Secretary.*

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* See Report of Committee on Steam Boiler Explosions, JOUR. FRANKLIN INSTITUTE, Vols. 19 and 20, new series.

BUILDING OF THE INTERNATIONAL ELECTRICAL EXHIBITION OF THE FRANKLIN INSTITUTE, 1884.

／ JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXVII. APRIL, 1884. No. 4.

MECHANICS—INTRODUCTORY.

By Prof. Coleman Sellers.

[Delivered at the opening of the course of lectures on Mechanics, Friday, November 9, 1883. Revised from report of Phonographer.]

(Concluded from page 172.)

In revising this lecture for publication in the Journal of the Franklin Institute, I cannot help giving another illustration of this uncertainty. An eminent scientist is reported as having stated that a horse-power is 33,000 lbs. raised one foot high, regardless of the time taken to raise it to that height; that 33,000 lbs. raised one foot high in a minute or in a day in each case expresses the same power. I cannot credit this and I will not do so unless the assertion comes to me in print from the hands of the author. It is so easy to misunderstand a speaker, and scientific lectures are not so correctly reported as lectures involving fewer technical terms.

So common is it to talk of the power of this or that machine as expressed by horse-power, that we feel as if its true definition should be part of every school boy's education. I think that it should be made a part of the tables of weights and measures that now form the school boy's early study. There should not be any one who could not tell, when asked, that what is known as a horse-power is a force equal to the raising of 33,000 lbs. one foot high in a minute, and that weight, distance, and time are the three essentials of horse-powers.

We can compute the power of the hoisting machines we have used in illustration this evening and determine the fraction of a horse-power a strong man can exert with either one of them, if we find what is the greatest load he can lift with the machine and the height to which he can raise it in one minute of time. The division of the weight lifted in the time named by 33,000 gives us the horse-power exerted.

In this city, noted for its great manufacturing establishments, there seems to be especial need of instruction that will fit the young of both sexes for work that will be remunerative sooner if the foundation of useful knowledge is in a shape for ready use. A well-grounded knowledge of the great law or principle of conservation of energy should be taught with the multiplication table. It can be so taught if the teachers themselves are certain that there is in the universe only so much energy and that we cannot make one particle more than already existed. With a clear understanding of this principle no time will be wasted in search after perpetual motion machines, and fewer mistakes will be made by really earnest seekers after improved machines for use or improved methods.

When a young man brings to me some wonderful improvement over the ordinary crank motion, some device that is to supersede the crank of the steam engine, a feeling of utter helplessness comes over me; I know not where or how to begin; he has had no opportunity to learn the simple laws of mechanics, and to point out the fallacy of his argument means to teach him the laws of mechanics, so I can only say to him "Don't," and may advise him what books to read.

We hear or read almost daily of the wonders of science and what is to be accomplished by electricity. "It is to be the great power of the future." Is it a power now? We may use it indirectly to drive machinery, we may make use of it to propel the cars on our street roads, but is it a power in the sense that steam is a power? Let us think of this a few moments. We call steam a power, and our factories are driven by steam power; or we call water when falling a power, and we drive the machinery in other factories by water wheels; or we pump water into the reservoirs at Fairmount by water power. Where we have no fall of water, and where fuel is scarce but wind plenty, we grind corn in a mill driven by wind, and the wind is our power; these and other sources of power may be called primary powers.

Secondary power is that which is transmitted from the prime motor

to a machine. One machine may be driven by belt power and another may be driven by gearing, etc. Electricity, as we now use it, as a power must be classed in its greatest economy with the secondary powers, with the belt or the gearing, not with the steam engine and the water wheel. We dig from the earth coal that contains the stored up energy of the sun's heat expended on forests that existed long before man came to live on this planet. We burn that coal under our boilers, and the steam generated by this application of heat to water is used to drive the piston of the steam engine and from thence is the power conveyed by belt or gearing, by shafts, or even by electricity, to the machines to be operated. We can burn up zinc in costly acids and generate electricity that can be used to drive an electric engine, and so in turn operate machines exactly as in the case of the steam engine. In this case electricity is a power exactly as steam is to be considered as a power, and what is more the electric battery will give us more nearly the whole of the stored-up energy of the metal eaten up in the battery than the most improved steam engine can give us of the stored-up energy of the coal that is devoured in the furnaces under the boilers. With all this advantage, electric batteries are not used to drive machines with any hope of economical results.

Zinc has been gathered from the earth as an ore, it has been converted into a metal, or the metal has been gathered from the ore by means of coal and much labor; its market price is measured by the cost of its production. To burn up zinc at five cents a pound in acids costing but few cents per pound, with a certainty of getting from the metal 70 or 80 per cent. of its theoretical energy in motive force, yet makes the venture a more costly one than the burning of coal under a boiler with the knowledge that we are at the best getting but little more than ten per cent. of the theoretical power that lies hidden in that coal. The electricity that is now lighting our streets, the electricity that is utilized in places to drive the street cars, has behind it the steam engine or the waterfall, the wind-mill or some other motor.

By means of a steam engine we drive a dynamo-electric machine, and the electricity thence proceeding lights our street or may be reconverted, with some loss, back into the power that created it; for one dynamo machine can be made thus to drive another, the electricity being carried from one to the other by proper conductors. What then is electricity as we now use it in the way of power but as the belts and the gearing that carries our steam power to the machines? It is a

belt with more or less slip. But this is not to remain so forever. The future of electricity as a power is full of promise. The coal we now squander, using but a small percentage of its theoretical dynamic force, is capable of yielding its energy either as heat or as electricity, and the time will come when we will not burn this coal to boil water and in that boiling lose say 1,000 units of its heat at the moment of the conversion of water into steam, lose all this never to be getting it back, but we will take from the coal its energy in the form of electricity we hope in more near ratio to its true value, and then we can convert that energy into whatsoever other form of energy we may require. The best that science can do is to point out just what energy there is in this or that source of power. The most we can hope to utilize of this energy as power will never amount to 100 per cent. Nature gives us nothing without exacting something in payment.

A pound of water is the same as a pound of metal so far as its power from gravity is concerned. In falling through space it will exert just as much force as any other pound weight is capable of doing and no more; it will do the work due to one pound falling at any given velocity less the friction of the machine or of the moving parts. We turn water into steam with a certain knowledge of the power that can be gained by using the elastic vapor as a spring, or we may tear the gases, which combined form water, apart and use these gases in recombination to produce power, but less power than was taken to tear them apart, never more.

Science has made us so sure of these facts that we can base our faith on them, and with this knowledge we are willing that others than ourselves shall invest their money in machines which are claimed to be able to develop from five drops of pure water inclosed in a ball, power enough to propel the largest steamship across the ocean. It is ignorance of the unalterable laws of physics that leads ignorant people into squandering money on so-called wonderful inventions that, out of nothing, are to give us great results. An ignorant man will spend his time pondering over perpetual motion machines, so will a man with brain gone wrong; the first will quit his folly with more learning, the second finds his home in the mad-house. A third and worse class aim to deceive and, for a time, many a one has done so. When shrewd ignorance resorts to dishonest methods, the confiding public is apt to suffer in pocket. I have here a curious document which I will read to you:

WHEREAS, The interference of the Legislature of Pennsylvania in causing an inquiry to be made, relative to the perfection or imperfection of newly invented machinery, is not without precedent;

AND, WHEREAS, It has been represented that Charles Redheffer, of the County of Philadelphia, has invented a machine declared, not only by the Inventor but by many intelligent persons, to possess the power of self-motion;

AND, WHEREAS, Should it be ascertained that those opinions are correctly founded, not only great honor would be conferred upon this Commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general;

AND, WHEREAS, On the other hand, should the machine be found to be imperfect, the public interest would be promoted by exposing its fallacy;

AND, WHEREAS, The Legislature of the Commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers and Oliver Evans, of the City of Philadelphia, Archibald Binney, Lewis Wernwag and Josiah White, of the County of Philadelphia, and Samuel D. Ingham, of the County of Bucks; therefore,

Resolved by the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, That Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wernwag, Josiah White and Samuel D. Ingham be and are hereby requested to make a strict examination of the machine invented by Charles Redheffer, and to make as specific representation respecting its alleged importance and the public expectation require.

Resolved, That the Secretary of the Commonwealth be and is hereby requested to transmit a copy of the foregoing preamble and resolution to each of the persons named therein, and also to Charles Redheffer.

JOHN TOD,
Speaker of the House of Representatives.

P. C. LANE,
Speaker of the Senate.

In the House of Representatives, December 14, 1812, read and adopted.

GEO HECKERT,
Clerk of the House of Representatives.

In Senate, December 17, 1812, read and adopted.

JOSEPH A. McJIMSEY,
Clerk of the Senate.

Now it so happens that we have in the Franklin Institute, Isaiah

Lukins's model of this, at one time celebrated perpetual motion machine. This is it on the table at my side. I presume it a correct model of the original, except that in this, the motion is obtained by clock work concealed in the base, and Reidheifer's machine was operated by means of a crank turned by a man or boy in the room below. In this model there are glass plates below the steps of the diving and driven wheels, that these plates can be taken out is assumed to offer convincing evidence that the wheels were not connected in any manner with any source of power outside of the machine itself. One can scarce look at this machine without feeling astonishment that any one should have been deceived by the wiley man, who claimed so much for it as to warrant an examination by a commission at the instance of the Senate and House of the State of Pennsylvania in General Assembly met. This was in 1812. I have talked with many who were active men at that time, and I know that its believers were numbered by thousands. One old man told me how, meeting a fellow traveler one night as he jogged out to his home in Montgomery county, they adjourned to a wayside inn, and there his companion made from an old cigar box a model to prove that Reidheifer's perpetual motion would do what was claimed for it. The sun was beginning to show itself when they were done with the interesting argument. Listen to the argument: "A loaded wagon will run down a hill. If the hill is steep enough, and the hill is capable of moving out from under the loaded wagon, then if the wagon is prevented from moving except in a vertical direction it will push the hill from under it. Now in this so-called perpetual motion machine there are two hills or inclined plains mounted on opposite sides of a wheel, which wheel is horizontal, its axis being vertical. There are loaded wagons on the two inclined planes and as the wagons cannot go down the inclined planes, but are held by a complicated system of levers and the inclined planes cannot move from under them, therefore the effort to do what both are prevented from doing, results in a constant push and the wheel is supposed to be driven around by this power." There are many stories told about this commission's visit to see the machine. One name on the commission is that of my grandfather, and his son, my father, went with him to see it and noted that while the large wheel was supposed to drive the small one, yet the wear on the teeth was on the side of the teeth that would indicate that the small wheel was driving the big one. It is said too that Isaiah Lukins, the maker

of this model, was also present and said the jerky motion of the machine was very indicative of a crank turned by hand-power. The commission found out nothing for they were not permitted to probe too deep, but they were none the less sure that gravity without motion in its own direction can impart no motion to other parts, no matter what complicated system of devices are made to take part in the fraud.

Another model was made that has since been destroyed by fire, which model could be taken apart and examined in detail, its bearings were on glass and when it was restored, all parts in proper position, it would show no signs of motion until the weights on the little carriages were placed on them and then the machine would run. I bring this old model to your notice this evening as a reminder of how very easy it is for those who are not well grounded in the fundimental laws of mechanics to be deceived. From the time of the perpetual motion machine of the Marquis of Worcester, down past Reidheifer in a time nearer to us, there have been presented innumerable such follies as this old model shows, and the world is full to day of those who if they had the money to spend would risk it in such foolish ventures. It is even said that in this present day there is not one hundred miles from where we now are, a greater wonder in the mechanical line. I persume it is so but I have not seen it.

In concluding this lecture I wish to show you an experiment and tell you how that experiment appears, to minds differently educated. What I will presently show you, I one time used, to test the inventive faculty of two very able men. One evening, some years ago, I had a visitor in the person of one of our most noted scientists, a man to whom I should go for information in the direction of his specialty, with the greatest confidence in the correctness of his judgment. The other man was an engineer, a member of this Institute. We were talking of the possible action of the mind on matter and the first caller, the professor, related some very remarkable things that had occured in his experience with a noted medium. What he had seen, seemed to him to prove the posession on the part of the medium of some power that was extraordinary and he argued that as his own habit of thought had been trained in the exact sciences, therefore, he could not have been the victim of any deceit. Wishing to test his inventive faculty which is what is required in considering such matters. I turned his attention to the then, rather new statements of certain very noted Englishmen that there existed a force or power with some per-

sons called, by one writer on the subject, physic force. This new force being shown in the power to will the change of weight in inert matter. I do not know if there has ever been any one who assumes to possess this power, who has exercised it in the direction of influencing the weight of the butter he had to buy in market, or of enabling the scale to weigh light when selling or heavy when buying. The fact is the examples given of the exercise of the power were on the whole rather useless. In fact, we may safely say, that there does not seem to be any great good derivable from the experiments published as tried in demonstration the existence of this force. I called his attention to a piece of apparatus I had made to show this force. Here it is. You see I have a ball of black wood about four inches in diameter, it is solid and through its centre is pierced a hole about $\frac{5}{16}$ of an inch in diameter through which hole I can pass this brass rod. The ball is in fact a large wooden bead and I can string this bead on a small cord, which about fills the hole but still the ball will slide freely on the cord, as freely as on the brass rod. The closest examination will show you nothing but the ball and the cord. The cord stretched tight is like a rod in the ball and it slides back and forth over the tense cord. This I gave to the professor to examine as much as he liked, letting him become familiar with it at his leisure; then, taking it in my own hands thus, I showed him that by the exercise of the physic force which I assumed I had in common with others, the ball would no longer show the same freedom of motion on the cord, except when I willed it to do so. See, I hold the cord vertically, one end under my foot the other held above my head. The ball remains near to my hand, and as I will it to do so descends as slowly or as fast as I wish it to. It is in fact under my control. See, I tell the ball to go to half the length of its string and its stops at the place indicated. Now this experiment continued to some length in order to give my friend the best chance to discover the method used by me, to restrain the motion of the ball only convinced him of the possession on my part of this so called new force. A force that sets at defiance the laws of physics that are most sure. A force that does not imply some newly discovered attraction, but controls one long and well known, namely the attraction of gravitation. Turning to my engineer, I asked him what he thought of the experiment? He replied, that he had never seen it before, but he should infer that, in as much as the ball was free to slide no matter what tension was made on the cord when it was in the hands of the

professor, that when I manipulated I had some means of increasing its friction, whereby I could control the amont of friction. I asked him how? For instance, he said, it is quite possible for the ball to be made with two holes in it, one passing through the axis of the sphere in a right line, and a second hole with its ends terminating in the straight hole, but the course of the second hole being made curved or crooked, then when the cord was threaded through the curved or crooked passageway, the friction could be controlled by the more or less tension of the cord. This was the true solution of the trick, for trick it was and is. A trick perhaps familiar to many of you, but interesting as a very clever device for testing the inventive faculty of those who see it for the first time.

Apart from the mechanical problems involved in the apparatus there is of course required the skill of hand, that enables the cord to be threaded into either one of the two passages, without any seeming hesitation in the simple act of threading the ball into the cord. There is a great deal of superstition hiding in all our minds and we are too apt to credit with some supernatural significance occurrances that are simple enough when we come to see them in the proper light. The training of the young should be more in the direction of a development of the inventive faculties, not to make an inventor of the grown up child, but to teach him how to view all things dispationately.

Lectures can do but a small point of this instruction, books must do more, and the public schools must be made to do their full share of the work of training, the hands, as well as the head. Under the wise direction of the present superintendent of public schools, we look for much good in this direction. It is our earnest hope that the present course of lectures may not only interest, but serve to illustrate what should be taught.

Cleansing Old Paintings—M. de Bibra begins by removing the dust with a brush, and washing with a sponge dipped in pure water. The surface of the picture is then covered with a thick layer of soap, which is removed after eight or ten minutes by a hard brush and water. After the last traces of soap are removed the picture is thoroughly dried, and rubbed with linen rags dipped in nitro-benzine. The cleansing is complete when the rags cease to be soiled. After again drying, the painting is covered with fine olive oil and varnished. —*Chron. Industr.*, Oct. 7, 1883. C.

INITIAL CONDENSATION OF STEAM CYLINDERS.

By William Dennis Marks,

Whitney Professor of Dynamical Engineering, University of Pennsylvania.

(Concluded from page 183.)

Possibly the greater economy of actual steam which it is claimed uniformly results from superheated steam lies in the certainty of *dry* saturated initial steam, the greater certainty of more complete re-evaporation during expansion, and the presence of less water on the interior walls of the steam cylinder demanding re-evaporation during exhaust than would occur with saturated steam.

Practically, superheating is done with the waste gases of combustion, and therefore cost nothing for fuel. Because what is called saturated steam is not always dry, we should not jump to the conclusion that under all circumstances it is the best plan to use superheated steam.

It may be the case with superheated steam that part of it (the main body) retains a greater specific volume than saturated steam.

Let us see what this increase of specific volume is in the case of the Harris Corliss engine.

We can say, with sufficient accuracy for our purpose at seven atmospheres.

	Pressure abs. Pounds.	Temp. Fahr. Deg's.	Specific volume. Vol's.
Saturated steam	102·9	329·6	265
Superheated steam	102·9	532	344
Difference			79

Making an increase of volume of 30 per cent. in the saturated steam, or a diminution in weight of about 20 per cent., volume for volume; but we must recollect that upwards of 50 per cent. of the weight of initial steam was condensed in the actual experiment on the Harris Corliss engine, and therefore if all the steam uncondensed in the steam cylinder at cut off be assumed to be superheated, the saving in weight would be much less than 20 per cent. of the actual weight of steam used.

Nor have we any guarantee that more than a small portion, if any, of the steam remains superheated. This point remains to be verified by experiment before becoming more than a hypothesis rendered probable by the known properties of steam and iron.

So far we have neglected both clearance and compression while engaged in submitting our assumed conditions to the test of comparison with actual practice, in the best examples we could find, both of condensing and non-condensing engines, with superheated, dry saturated, and wet steam.

It will be noted that a steam jacket was present in each case, and that the steam was not embarrassed by the presence of sluggish valve movements or of throttling to any considerable extent.

Indeed, it is not worth while to attempt discussion of the ill-designed and ill-conditioned engines which serve only to make the wheels of the machinery go round. The certainty of movement resulting from extreme simplicity may be safely taken as an equivalent in peace of mind, which will compensate their owners for loss in pocket, so long as the loss is the owners' and not ours.

If we substitute $\left(e - b\,\frac{B}{P_b}\right)$ for e in equation (11) and differentiate for a maximum with respect to e, we have

$$e = \frac{B\left[1 - b\left(1 - \text{nat. log. } \frac{b}{k}\right)\right]}{P_b} + k + \left\{\frac{\frac{2D}{s} - \frac{Bb}{P_b}\left[A + \frac{4D}{d}\right]}{A + \frac{4D}{d} + \frac{Bb}{P_b}\,\frac{2D}{s\,e^2}}\right\}\text{nat. log. } \frac{1}{e} \qquad (16)$$

Particular attention need not be paid to the clearance and compression, except under unusual circumstances. Equation (15) must then be used to obtain a first value, which can be substituted in the second member of (16) one or more times, in proportion to the accuracy required.

Compound engines lay claim to greater economy of steam than simple engines, and the fact is undeniable that compound engines have produced economical results much more certainly than simple engines. The advocates of simple engines urge with perfect justice that com-

pound engines always have higher pressures of steam, more expansion, relatively lighter loads and more careful construction for steam economy than simple engines.

If, now, we assume the case of compounded cylinders, with cranks together or 180 degrees apart, no receiver, no drop in the expansion, no cut-off on the condensing cylinder, and no clearances or compression, we have (see Economy of Compound Engines, this JOURNAL, Jan., 1884), from addition of the equations for the work of the two cylinders,

$$PV = V_n \left\{ eP_b \left[1 + \text{nat. log. } \frac{R}{e} \right] - RB \right\} \tag{17}$$

or in terms of the volume of the condensing cylinder and of the ultimate expansion, since $\frac{R}{e} = e$

$$PV = V_e \left\{ \frac{P_b}{E} \left[1 + \text{nat. log. } E \right] - B \right\} \tag{18}$$

That is to say, mathematically it can be shown, the same measure of expansion being used in both cases, the power of the condensing cylinder alone is equal to the combined powers of the two cylinders of a compound engine, and if we neglect initial condensation the steam economy is the same. Let us see if the economy is the same.

Substituting (17) in equation (11), and differentiating, we have, for the cheapest cut-off for compound cylinders,

$$e = \frac{RB}{P_b} + \frac{2Dd}{s\,[Ad + 4D]} \text{ nat. log. } \frac{R}{e} \tag{19}$$

and substituting (18) in equation (11), and differentiating for a maximum, we would have, for a single cylinder,

$$\frac{1}{E_1} = \frac{B}{P_b} + \frac{2D_1\,d_1}{s\,[Ad_1 + 4D_1]} \text{ nat. log. } E_1 \tag{20}$$

We have carefully followed the action of the steam while passing through one cylinder. Let us follow it through the two cylinders.

The steam entering the non-condensing cylinder suffers initial condensation, in some instances quite copious, but not so great as if the non-condensing cylinder had the temperature of the exhaust, T_e; however, the cut-off being later than would occur with the same ultimate expansion, E, in a single cylinder, the initial condensation will be found to be very considerable.

The steam being cut off in the non-condensing cylinder, re-evaporation begins, the expansion line being held closely to an equilateral hyperbola.

This re-evaporation is, however, far from being complete, and at the end of the stroke communication is opened to the condensing cylinder. At this instant a relatively enormous initial condensation occurs, because of the great surface of condensing piston and cylinder head presented at the temperature of exhaust, but this condensation is met at once by the equally as active re-evaporation which simultaneously occurs from the whole interior of the non-condensing cylinder, the result being the transferring of the condensation from the surface of the non-condensing cylinder to the surface of the condensing cylinder until the temperatures are equalized.

After the violence of this first transfer of condensation has abated, the re-evaporation from the interior of both cylinders occurs with sufficient alacrity to hold the expansion curve closely to an equilateral hyperbola.

If but two cylinders are used, the condensing cylinder is now opened to exhaust and the re-evaporated and vaporous steam enter the condenser, carrying much more heat than would appear from a calculation of the thermal value of the vaporous steam present at the end of expansion.

Thus we see that at the present day the compound engine owes its possible greater efficiency to the physical attributes of iron rather than to the properties of steam, and that with the use of non-conducting materials the necessity of compounding cylinders will vanish.

It does not seem as if the possible use of non-conducting surfaces for the cylinders and piston heads would greatly improve the state of affairs, since then the barrel of the cylinder, assumed of iron, would act with greater energy and consequently probably diminish the pressures much more rapidly than is now shown to be the case by the indicator diagram. This hypothesis will have to be subjected to the test of experiment before carrying any weight.

When cranks of compounded cylinders are placed at right angles and the steam is cut off from the condensing cylinder at an early point in the stroke, certainly earlier than ½ stroke, it will be found that a considerable increase in the economy will occur with a small receiver, although this arrangement will cause trouble in equalizing the power

of the cylinders because of the increase of back pressure in the non-condensing cylinder until its piston reaches mid-stroke.

This economy arises from the fact that the transferrence of condensation from the non-condensing cylinder to the condensing cylinder is greatly facilitated by an increased difference in temperatures of the non-condensing cylinder and receiver and of the condensing cylinder.

The particularly injurious effect of a double admission of steam to the condensing cylinder, when cranks are at right angles and the cut-off of the condensing cylinder is later than one-half stroke, arises from the fact that this re-evaporation from the iron surfaces is temporarily stopped by the entrance of steam of a higher temperature from the non-condensing cylinder.

If now, in equation (19), we substitute $\frac{R}{E}$ for e, we have for compounded cylinders

$$\frac{1}{E} = \frac{B}{P_b} + \frac{2Dd}{Rs\,[Ad + 4D]} \text{ nat. log. } E \qquad (21)$$

Equation (21 places the point of cut-off theoretically for compound engines which gives the least cost, under the assumptions made, and the point of actual cut-off in the non-condensing cylinder can be determined from $e = \frac{R}{E}$ or equation (19).

The further condition that the power of the two cylinders shall be equalized, results in the equation of condition.

$$\text{Nat. log. } E = \frac{2R}{R-1} \text{ nat. log. } R - \left[1 + E\frac{B}{P_b}\right] \qquad (22)$$

or, in common logarithms,

$$\text{log. } E = \frac{2R}{R-1} \text{ log. } R - \frac{\left[1 + E\frac{B}{P_b}\right]}{2 \cdot 3026} \qquad (23)$$

Approximate values of R, E and e under these conditions will be found tabulated in "Economy of Compound Engines" [continued from January, 1884, in the April number of this JOURNAL], the term $E\frac{B}{P_b}$ being neglected as being very small, as it usually is.

In the compounded cylinders assumed there is no cut-off on the

condensing cylinder and, therefore, T_e corresponds in equation (14) to the pressure $\frac{P_b}{E}$.

Let us make the following assumptions and compare the results:

Initial pressure abs. $= P_b = 100$ lbs. per square inch.
Back pressure abs. $= B = 2$ lbs. per square inch.
Length of stroke $= s = 4$ feet.
Diameter of condensing cylinder $= d_1 = 4$ feet.
Ratio of cylinders $= R = 2\frac{1}{2}$.

Diameter of non-condensing cylinder $= \frac{d_1}{\sqrt{R}} = d = 2{\cdot}53$ feet.

Temperature of initial steam $= T_b = 327{\cdot}57°$ (dry saturated).
Temperature of exhaust steam $= T_e = 126{\cdot}27$.
Specific vol. initial steam $= S = 267{\cdot}9$.
No. of strokes $= N = 150$ per minute.

$D = \frac{T_b - T_t}{100N}$ in which T_t denotes the temperature at terminal pressure of non-condensing cylinder.

$D_1 = \frac{T_b - T_e}{100N} = {\cdot}01342.$

$A = \frac{62{\cdot}5}{S} = {\cdot}2333.$

If now we substitute these values in equation (20), we have for the point of cut-off in a single cylinder

$$\frac{1}{E_1} = \frac{2}{100} + \frac{2 \times {\cdot}01342 \times 4 \times 2{\cdot}3026}{4[{\cdot}2333 \times 4 + 4 \times {\cdot}01342]} \text{ com. log. } E_1$$

$$\frac{1}{E_1} = {\cdot}02 + {\cdot}0625 \text{ com. log. } E_1$$

Assume $E_1 = 11$ or $\frac{1}{E_1} = {\cdot}09$, we have

$${\cdot}09 = {\cdot}02 + {\cdot}0625 \times 1{\cdot}041 = {\cdot}083.$$

That is to say, the point of cut-off will be found to be between $\frac{1}{11}$ and $\frac{1}{12}$ of the volume of the cylinder. Other considerations might in actual practice prevent so great expansion.

We can next take up the compounded cylinders. Assuming some-

thing over 12 expansions as probable in this case, let us take the terminal pressure of the condensing cylinder as 7 lbs., we have $T_t = 176{\cdot}91$

$$D = \frac{T_b - T_t}{15{,}000} = \frac{150{\cdot}66}{15{,}000} = {\cdot}0100$$

Substituting these values in equation (21) we have

$$\frac{1}{E} = \frac{2}{100} + \frac{2 \times {\cdot}01 \times 2{\cdot}53 \times 2{\cdot}303}{2\frac{1}{2} \times 4\,[{\cdot}2333 \times 2{\cdot}53 + 4 \times {\cdot}01]} \text{ com. log. } E$$

$$\frac{1}{E} = {\cdot}02 + {\cdot}02 \text{ com. log. } E\,.$$

If we assume $E = 18$, we have

$${\cdot}055 = {\cdot}02 + {\cdot}025 = {\cdot}045$$

or, assuming $E = 20$, and neglecting T_t we have

$${\cdot}05 = {\cdot}02 + {\cdot}026 = {\cdot}046$$

and so on until we reach an equality of the two members of the equation of condition, but it has been shown in this JOURNAL, Dec., 1883, that, all condensation being neglected, the saving by expansions surpassing 8 or 9 times is so small as not to render it worth while, from a financial point of view, to go much beyond that amount had we cylinders which were perfect non-conductors of heat. In fact we have not data justifying us in assuming that the re-evaporation from the non-condensing cylinder is efficient to any very great extent in keeping the expansion curve close to an equilateral hyperbola.

It would seem, however, that compounded cylinders do have the advantage of enabling greater expansions of steam and a greater actual economy, but they owe this advantage to the physical properties of iron not of steam.

A steam jacket in which live steam with the water thoroughly drained has been assumed for every case, as has also that sufficient superheating to insure dry steam in the steam chest. It would appear as if superheating to any greater extent remained a point to be proved of value should we adhere to iron cylinders. As compared with the total heat of steam, the amount of heat which can be added by superheating is very trifling unless we superheat to a dangerous extent.

If we assume a given number of expansions, *E*, which we have found *adapted to the size of engine proposed,* we can compare the

economy of a compound engine and of a simple engine with a cylinder of equal size with the condensing cylinder of the compound engine.

The work put upon the engines should be the same in both cases.

Formula (12) can then be used in each case and the resulting values of y compared.

It should be borne in mind that the proportions of the parts of an engine are functions of the initial pressures while the economy is not.

This would raise the frictional resistance of an engine with its size and with the increase of initial pressure.

The writer is not disposed to insist upon the accuracy of his present theory of condensation in more than a general way.

It has shown, however, that the wide differences in experimental results of tests of different types and sizes of engines are not irreconcileable, and that the builder of small engines of the non-condensing type is quite as right in adopting 4 expansions as the builder of enormous marine engines of the compound type is in adopting expansions of 10 or more volumes.

The data upon which the present theory is founded are all subject to revision, as they can lay no claim to scientific accuracy.

The question as to the influence of the time of exposure cannot be regarded as settled by any means and cases in which the number of strokes varies greatly from 150 may not be properly met by his formulæ.

The influence of the difference of temperature may well be subjected to thorough scrutiny in the case of superheated steam.

The effect of superheating upon the specific volume has been reduced to law by the labors of Hirn and Zenner [a most excellent resumé of their labors may be found in "Roentgen's Thermo-dynamics," translated by DuBois, published by J. Wiley & Sons, New York] but it remains to be proved that the specific volume of the steam existing in the cylinder as vapor at the point of cut-off does or does not differ from that of saturated steam.

The possible leakage of the Harris Corliss engine is far from being disproved. Repeated inquiries have failed to obtain an expression of opinion from Mr. Hill, whose language is not clear or consistent on this point of his report of 1880.

Page 4. "All the engines were new and leaked slightly through the valves and possibly in one instance past the piston during the trials. Mr. Ellis, of the Harris engine, attempted to hasten the seating of the

steam valves of his engine by filing previous to the trials with good results, as shown by the diagrams."

"No effort was made with either the Reynolds or Wheelock engine to seat the valve except by wear."

Page 6. "The trials were made in accordance with the following code of regulations, excepting (possibly to the credit of two of the contesting engines) no test was made of the tightness of the pistons."

Page 74. "The percentage of steam accounted for is very low with all the engines and is attributable largely to the natural leaks of new engines comparatively unworked. These engines would have shown better economy after a continuous use with a fair load for a period of two or three months, but with the natural leaks through valves and past pistons and a steam pressure higher than usual, it is not surprising that the engines accounted for a low percentage of the steam actually delivered to the cylinder."

It is of interest to compare this last statement of Mr. Hill with the language of G. A. Hirn, *Theorié Méchanique de la Chaleur*, 1876, Vol. II, page 55.

"In comparing the actual cost of our engines per stroke with the theoretic cost obtained by multiplying the volume opened to the steam by the density of this vapor supposed superheated, I always found the first result very much higher than the second. For a long time I continued to believe that this increase of cost arose from piston leaks. These leaks seemed to me both natural and probable, since we were working (as I then believed) at a very high temperature, capable of destroying or evaporating the lubricants used in the cylinder to diminish the friction and wear of the parts.

"I yield to M. Léloutre the whole merit of having opposed these views, of having suggested to me as both possible and probable the existence of condensation of steam during admission resembling a loss by leakage, and giving to the steam a density much greater than would be obtained by calculation. I yield to him the merit of having in a manner forced me to make new experiments which would by various methods bring the truth to light."

The writer is forced by Mr. Hill's silence and ambiguity on the point of leakage to use his own judgment in selecting a set of experiments for the calculation of the value of C (the weight of steam condensed by 1 square foot of cylinder surface heated one degree Fahr. in

one minute.) This should be an average of many experiments on different engines.

The method of treatment used is only one of many which have been relinquished because of giving impossible results when laboriously elaborated from actual data more or less deficient on important points.

So far as he knows, the writer's method is original, and has been adopted mainly for the purpose of rendering the results intelligible to those who are actually engaged in the designing and care of engines.

He would earnestly request the assistance of those in position to furnish experimental data, *to be used for scientific purposes only*, and will be pleased to send a memorandum of the methods of experimentation, and of the data required for this purpose, to those who may desire it.

His own movements are too limited, and his time too fully occupied by his duties as a pedagogue, to allow him the hope of completing the experiments necessary to a complete test of the theory put forth.

Philadelphia, January 12, 1884.

Since writing the above we have received a letter from Mr. Hill from which we quote as follows:

CINCINNATI, *February* 2, 1884.

DEAR SIR:—The calorimeter used in the tests for quality of steam at the Miller's Exhibition was of the continuous kind, carefully made and in charge of my principal assistant.

I accepted his notes and data as correct at the time, but from more recent experiments am inclined to doubt any result from a calorimeter of this kind, owing to the fact of large variations in the temperature of overflow (known to subsist by other circumstances) not recorded by the ordinary mercurial thermometer.

I now use a simple arrangement of tub, scale and hand thermometer, and while this method is liable to error, the error is not sufficient to lead you astray.

For the purpose of comparison I regard the calorimeter data of the Miller's Exhibition trials as correct, but cannot endorse it for absolute results.

* * * * * * * * * * *

I know the Harris piston was tight from special test.

Page 74. There is no doubt all the engines suffered from leaks into and out of cylinder through steam and exhaust valves.

* * * * * * * * * * *

I shall always be happy to give you any information in my power, but

owing to a busy professional life, may not be as prompt as you desire in replying to inquiries.

Very sincerely yours,

JOHN W. HILL.

Mr. Hill's statements from his actual knowledge happily corroborate our own inferences from his data and diagrams, and therefore add weight to the results.

Philadelphia, February 4th, 1884.

AN INVESTIGATION LOCATING THE STRONGEST OF THE BRONZES.

By W. Ernest H. Jobbins, M. E.

(Concluded from page 199.)

Part V.

Investigations of the Author.

The work of the writer has been confined to tests by Prof. Thurston's Autographic Recording Testing Machine, and from the results thus obtained the desired values have been deduced by means of different formulæ. These results are far more accurate and reliable than could be obtained, so far as the writer is aware, by any other means; and it was possible to carry on the work with much greater rapidity. Owing to the short period of time at our disposal, it was impossible to make as exhaustive an investigation as was desired; but it is hoped that the results given will be found to be valuable. To a very slight extent these results may be considered approximate, as it was not possible to make chemical analyses of the test-pieces; but the work has been conducted with such great care and the alloys have been fluxed so carefully, in every case, with phosphorus, that the loss in casting has been reduced to a minimum.

The area chosen as the field of this investigation was a small triangular portion surrounding the peak of the mountain, Fig. 4, Part III, marked 65,000 on Fig. 3, Part III, since it was found, after a close study of Figs. 3 and 4, that this area embraced all that portion of the field in which the most tenacious alloys had hitherto been discovered. The data obtained from this investigation prove the correctness of this decision; for, though there was found a wide range in the values

obtained for the different specimens, yet they all gave exceedingly high figures, the lowest average value of tenacity being 51,139. As this research extended over but a very limited area, it has been possible to conduct the investigation with a much greater degree of exactness than has been attempted before; and subsequent investigations, covering a still smaller field, should settle beyond dispute the composition of the "Strongest of the Bronzes." Practically this research accomplishes that result.

The metals varied by differences of but one per cent. in each case, and 23 combinations were chosen; two test-pieces were made of each composition, making forty-six test-pieces in all. In the majority of cases, the data obtained from the two specimens of the same composition agreed so closely that the average value was safely made use of; but, when there was any very marked difference, the data agreeing more closely with the results anticipated from analogy were adopted, and the other value was rejected as being probably erroneous Had there been time for a chemical analysis, each specimen would have been treated separately whenever the analysis revealed any considerable difference of composition. The metals employed were of the very best commercial quality; it has been the intention throughout to obtain the maximum practical results. The copper employed was Lake Superior; the zinc, Bergen Port. Both of these metals were obtained from the Ansonia Brass Company.

In the use of tin a new departure was made; it is stated that "phosphorus is used in insuring soundness in the better class of copper-tin and copper-zinc alloys, which metals are very liable to be made seriously defective by the absorption of oxygen and the formation of oxide." After years of experiment it has been found possible to produce, on a large scale, an alloy of phosphorus and tin, which, while containing a maximum percentage of phosphorus, does not give off phosphorus when remelted. The best proportions for practical use are tin 95 per cent. and phosphorus 5 per cent. It was decided to use phosphor-tin, and the amount required was obtained from Messrs. Alfred Barber & Co., of Hamburg.

The first step was to determine the exact limits of the field selected. This was quite a difficult matter, but after careful study the following were decided upon: Copper, maximum 60, minimum 50; Zn, 48 and 38; Sn, 5 and 0. It will be noticed that these limits include the "Tobin Alloy," and also that one which Prof. Thurston mentions in

his paper as being "the best alloy for purposes demanding toughness as well as strength." Its tenacity is 68,900 pounds per square inch (4,841 kilogrammes per square centimetre). A very appropriate name for this alloy would be the "Thurston Alloy," but not his "maximum alloy," which it is here sought to identify, and it will be so designated in this paper. It was not practicable to include all the combinations possible within these limits, but twenty-three were chosen; their compositions are given in the following table :

TABLE I.

Proportions of Selected Alloys.

No.	Cu.	Zn.	Sn.	No.	Cu.	Zn.	Sn.	No.	Cu.	Zn.	Sn.
1	55	43	2	9	53	43	4	17	58	40	2
2	54	44	2	10	55	41	4	18	54	45	1
3	54	43	3	11	57	41	2	19	53	44	3
4	55	42	3	12	57	43	0	20	54	42	4
5	56	42	2	13	55	45	0	21	56	41	3
6	56	43	1	14	52	46	2	22	57	42	1
7	55	44	1	15	52	43	5	23	58	41	1
8	53	45	2	16	55	40	5				

The exact proportion of each alloy having been determined upon, the metals were weighed on the standard United States balance in the Physical Laboratory of the Stevens Institute of Technology, as described in Part IV. These weighings were made with the greatest care, as but small quantities of the various metals were used. The total weight of each test-piece was 1·45 pounds (657·70984 grams). The work of casting the test-pieces was performed in the brass foundry of the Institute; the castings were made in an iron mould, 8 inches long and 1 square inch cross-section. A mixture of plumbago and water was employed as a "blacking" for the interior of the mould, in order to reduce the friction between the sides of the mould and the cast metal to a minimum, and to prevent the test-pieces from adhering to the sides of the mould.

The copper was first placed in the crucible, and was then covered with powdered charcoal to prevent contact with the air and oxidation of the molten metal. After the copper was melted its temperature was raised, so that when the zinc was added and the consequent reduction

of temperature occurred it might not be sufficient to produce partial solidification of the metal; when this chilling occurred it became necessary to remelt the alloy, and a considerable loss of zinc was thus occasioned. Great care was taken in introducing the zinc, the metal being carefully wrapped in paper, which permitted its introduction beneath the surface of the molten copper before it could be acted upon by heat or by free oxygen; in this way a considerable loss of zinc was prevented.

The molten metals were thoroughly stirred, and the crucible removed from the furnace, after which the tin was added, the same precaution being observed as with the zinc; after another thorough stirring the metal was poured into the iron mould, which had previously been heated. The casting was then cooled as rapidly as possible. The pieces were marked as they were cast. There being two pieces of each number, they were marked, respectively, A and B. The castings were then made into test-pieces of the form and dimensions described in Part IV. Though there was a great difference as regards the brittleness of these pieces, yet none of them were so hard or brittle as to be unfitted for practical purposes, and they were all turned up in the lathe with comparative ease.

The writer next examined and discussed the data obtained in the endeavor to arrive at some definite conclusion concerning the composition and position of the "strongest of the bronzes." All the surfaces of the fractured test-pieces were very carefully examined under a strong lens. It was found impossible to detect the slightest defect in them. The figures were deduced from the curves obtained by the Autographic Recording Testing Machine. The formulas used in this investigation are as follows: $M = Wh - f$, where w = weight necessary to deflect the pencil one inch; h = height of the curve above the base line at θ_r, the angle at rupture; f = friction, and M is the torsional moment.

In this case, $w = 96{\cdot}93$ foot-pounds, and $f = 4{\cdot}75$, h being measured on the Autographic Record of each test-piece; T is the tenacity. In order to obtain the required values of T we use the formula given by Mr. Baird,* as follows: $T = [300 - \frac{1}{3}\theta_r]\,M$, in which M is known, and θ_r is measured directly from the Autographic Record The values of M, T, θ_e and θ_r, as obtained from these data, have been tabu-

* A newly discovered Relation between Tenacity and Resistance to Torsion; R. H. Thurston. Trans. Am. Soc. C. E., July, 1871.

lated; the average values of M and T have been deduced, and are included in the following table (θ_e is the angle limit) at elastic:

TABLE II.

Strength of Copper-Tin-Zinc Alloys.

Original Mark And No.		Stress in Torsion. Foot-pounds. Ultimate. M.	Stress in Torsion. Foot-pounds. Average.	Approximate. Stress in Tension. Pounds per Sq. Inch. Ultimate. T.	Approximate. Stress in Tension. Pounds per Sq. Inch. Average.	Angles. θ_e	Angles. θ_r
I X I 1	A	270·208	261·065	77309·5	74805·6	1·5°	43°
	B	251·922		72301·6		1°	40°
O B 2	A	178·321	193·361	53946·3	56653·6	1·1°	5·05°
	B	208·400		59810·8		0·7°	40°
Z 3 3	A	251·922	235·929	75576·6	70778·6	1°	13·77°
	B	219·935		65980·5		1°	10°
J 4 4	A	243·392	250·851	73017·6	73965·1	2°	19·8°
	B	258·319		74912·5		2°	30·3°
F 5 5	A	268·881	266·212	75824·4	75467·1	4·6°	55°
	B	263·543		75109·8		2°	46°
G 6 6	A	227·689	224·151	64208·3	63700·9	2·5°	53·3°
	B	220·612		63193·6		2°	42·1°
K 7 7	A	286·847	268·851	80910·9	75826·0	2°	54°
	B	250·855		70741·1		2°	53°
R 8 8	A	194·634	189·488	58390·2	56844·8	2°	9·1°
	B	184·331		55299·3		2·69°	5·72°
S 9 9	A	222·853	226·725	66853·9	68017·5	1·5°	5·78°
	B	230·597		69179·1		1·79°	4·5°
L 10 10	A	249·014	250·948	74704·4	75284·4	2·1°	4·6°
	B	252·881		75864·3		2·8°	8·8°
Z 11 11	A	260·645	249·014	74269·2	69116·8	2·4°	39·8°
	B	237·382		63964·3		1·9°	35°
D B 12	A	227·689	234·474	61020·7	61390·5	2·3°	95·2°
	B	241·259		61762·3		1·6°	131·4°
M 13 13	A	227·689	217·996	64208·4	61058·3	2°	52·4°
	B	208·303		57908·2		1·1°	65°
U 14 14	A	163·715	170·450	49113·5	51139·5	2·3°	4·9°
	B	177·185		53165·5		2°	7·2°
V 15 15	A	189·886	208·788	56965·8	62636·3	2·6°	4°
	B	227·689		68306·7		2°	5°
N 16 16	A	225·750	239·974	67725·5	71842·2	1·6°	3·8°
	B	253·198		75959·4		1·6°	6·8°
A 17 17	A	227·689	238·771	63200·3	68344·3	1·4°	54°
	B	250·952		73488·3		1·8°	43·2°
P 18 18	A	254·829	259·737	72871·1	72186·5	1·6°	43·4°
	B	260·645		71501·9		1·8°	54°
T 19 19	A	231·566	214·119	69459·8	64230·6	2·2°	8°
	B	196·671		59001·3		1·4°	4·8°
Q B O 20	A	229·628	244·168	68888·4	73250·3	1·6°	6·4°
	B	258·707		77612·1		1·8°	7·2°
H B I 21	A	283·908	266·768	81381·6	75135·0	2·9°	38°
	B	229·628		68888·4		2·4°	8°
E B B 22	A	305·233	263·508	85770·5	73378·6	2°	56°
	B	221·773		60986·6		2·5°	76°
B 33 23	A	225·750	200·499	63084·3	54061·4	1·6°	63°
	B	175·247		45038·5		1·2°	128°

From these tabulated results, and by comparison with the general characteristics of the test-pieces, the writer has determined the position of the strongest alloys very approximately. Later investigation may,

to a very slight extent, change the position of the strongest alloy. In the diagrams, which represent that portion of the field investigated, the positions of the alloys discussed are plainly marked, the numbers corresponding to those in the table just given; the other figures are explained upon the diagram. Diagram I locates the alloys.

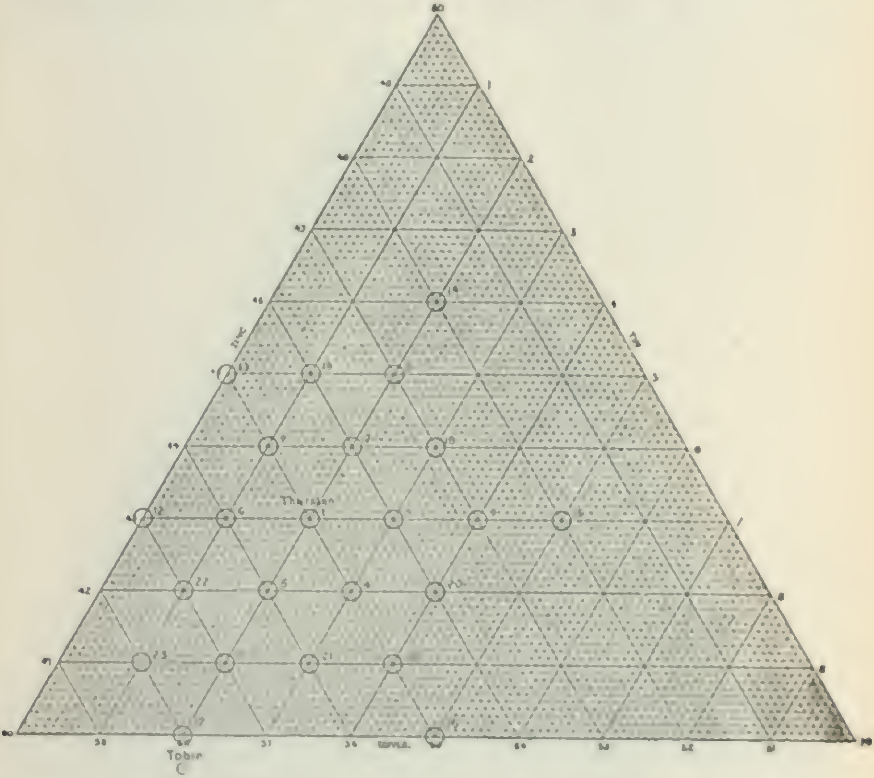

DIAGRAM I.—LOCATION OF ALLOYS TESTED.

Diagram II is based entirely upon the results obtained by the torsion tests. Diagram III exhibits the tensile strengths of the specimens. Diagram IV gives the positions of the alloys as determined by a study of II and III, and the general characteristics of the test-pieces, and may be considered practically exact. One more word of explanation in reference to diagrams II and III is necessary: In order to insure absolute certainty as to the position of the "strongest alloy" every precaution was taken to avoid error. On these two diagrams, the alloys are arranged in three different series: 1st. According to the average values

of M and T; these are marked A. This series would be correct if both castings of each specimen were exactly alike, a fact which a chemical analysis alone can settle beyond doubt. 2d. According to the highest values of M. and T, and are marked B; this series was arranged in the supposition that that the lesser values were given by poor castings, and did not represent the true strength of the alloy. 3d. After a

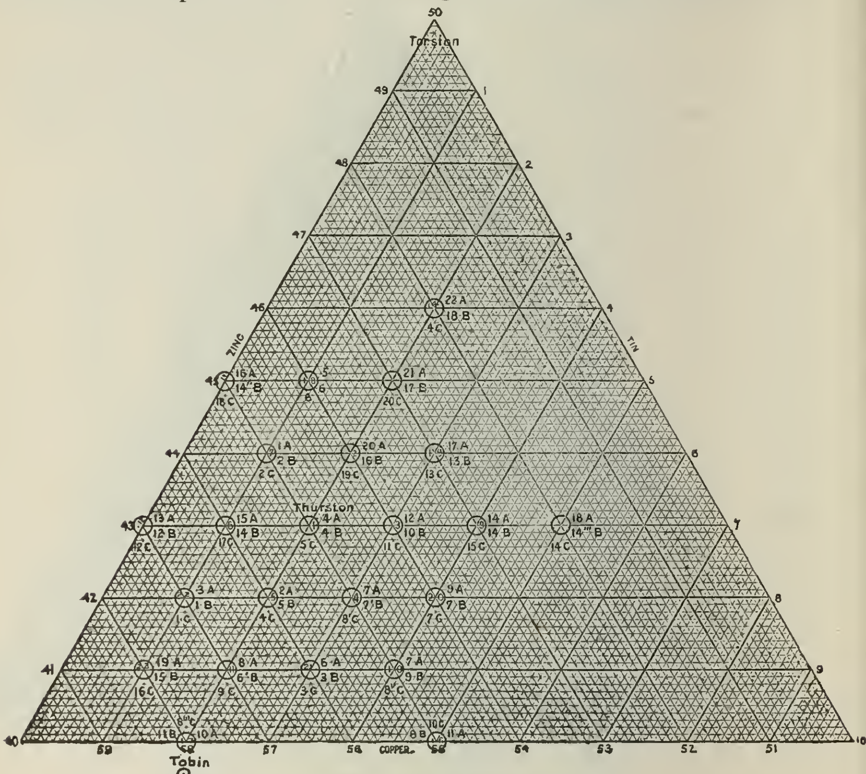

DIAGRAM II.—RESULTS OF TESTS BY AUTOGRAPHIC MACHINE.

careful scrutiny of the table, p. 264, it will be noticed that the values of M and T obtained for both specimens of the same alloy, in some cases agree very closely; when this was the case the average values were taken. In other cases the differences were very large; under such circumstances the higher values were used. From these two classes the 3d series was formed; thus it will be seen that this series is, in reality, a combination of the 1st and 2d. This series is marked C. Diagram IV was formed from a careful study of diagrams II and III. From these remarks, it will be seen that it was a matter

of some difficulty to decide satisfactorily as to the relative positions of the alloys.

The first step was to determine which alloy should be entitled to the first position; there were two rivals for this position, Nos. 7 and 22. *No. 7.*—This was a fine alloy, with a smooth, even fracture, whose surfaces presented a tough fibrous appearance and which twisted apart slowly and evenly. *No. 22.*—This was an alloy, golden in color

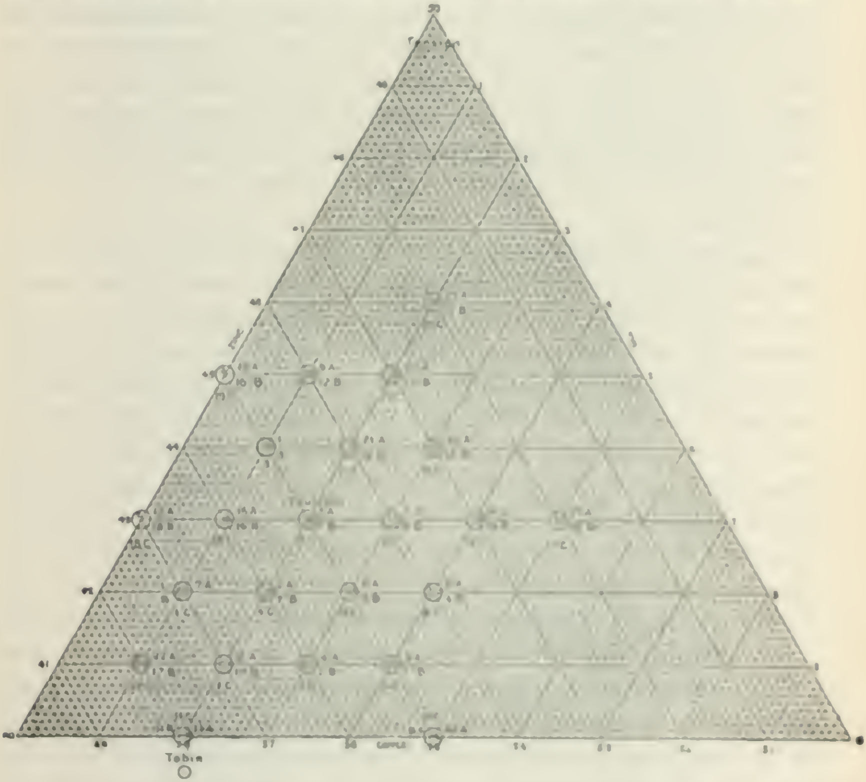

DIAGRAM III.—TENACITY OF THE "MAXIMUM" ALLOYS.

and very close grained and gave a fracture in all respects similar to No. 7, and was exceedingly tough. Thus, in appearance and general characteristics, these alloys were exceedingly alike. Consulting diagrams II and III, it was found that, when the average values of M and T were used, No. 7 stood first upon the list and No. 22 third and seventh; while, in each case, when the higher values were taken, No. 22 was first and No. 7 second and third. After a careful examination

of the values obtained for No. 7, it was thought best to consider A and B as specimens of the same alloy for the values of M and T for B, though differing considerably from those of A, are very high, and the values of θ_t and θ_r are very similar; therefore, for this alloy, the average values were taken. In the case of No. 22 there was not only a great difference in all the values of A and B, but B, while giving very low values for M and T, gave a very high figure for θ_r; this would indicate a change in composition either from volitilization or from some other cause; hence A and B have been considered as two independent alloys and B is thrown out as a weak, though ductile alloy, The values of No. 22 A being by far the highest obtained, this must be considered the strongest alloy, and No. 7 stands second upon the list. It is an excellent alloy, giving exceptionally high values for its moduli.

The next upon the list is No. 21. In this case, the values of A were alone considered, for those of B were much lower and the casting was defective and very brittle and had a ragged, uneven fracture. It showed signs of considerable liquation. "A" was a very excellent specimen and gave values of M and θ_r nearly equal to those of No. 7, and the value obtained for T was higher than the corresponding value for No. 7, in fact this value was exceeded by that of No. 22 only. The metal was of a bright straw color and had a smooth, regular fracture and considerable ductility; it was a very close third. While the values of M and T, for No. 1 A, were higher than either of the corresponding values obtained for No. 5 A and B, yet, in each, there was such a very small difference between the values obtained for A and those obtained for B, that it was impossible to do otherwise than to consider them as two pieces of the same alloy; consequently average values have been considered. This places No. 5 fourth and No. 1 fifth. No. 5 was a very fine alloy, possessing great ductility and giving a good smooth, square fracture and the grain was very close and compact. But higher results can undoubtedly be obtained from an alloy of this composition; for these specimens showed signs of slight liquation.

No. 1.—This was a tough metal, the pieces being twisted apart slowly, not snapping suddenly, as in the previous case; better results should be expected from this alloy, for it exhibited signs of an imperfect mixture of the metals. This was the strongest alloy reported by Professor Thurston to the American Society of Civil Engineers, and

described in Part III. The sixth position has been assigned to No. 11. It has been thought better to throw out all the values of B, as all the indications were, that, though a ductile specimen, it was still a very weak one and it does not fairly represent the strength of this alloy. A gave a fine regular fracture and had high ductility; it twisted apart slowly and evenly. Its values for M and T were very high. The next upon the list was No. 18. This was a good alloy, and although more crystalline than those previously mentioned, had a smooth fracture and high moduli; it was very ductile. In the case of B, there was considerable liquation; but its torsional strength was very high and its value for T a very fair one. The eighth upon the list, No. 10, though it gave high values for M and T, was still a very brittle alloy; its values for θ_r being 4·6° and 8·8° and its color gray, with a fracture closely resembling that of steel. Its tensile strength was very great, being 75,000 pounds, a higher figure than some of the preceding alloys have given; but its value for M was much lower. It was a very hard metal. No. 4 stands ninth and has even higher values for T than No. 18, but its other values were much lower. There was considerable liquation with A, while it exhibited a fracture that was smooth and regular, and it broke off slowly and evenly. In color it was a light yellow. B broke off suddenly, giving a rough granular and uneven fracture; it was of a very light gray color, indicating a brittle metal; but its values of θ_r were good, and it was quite strong. In this alloy there was 1 per cent. more zinc and 1 per cent. less tin than in No. 10, and, though yielding slightly lower values for M and T, it was far more ductile; and had there not been any liquation these values would have exceeded those obtained for No. 10. Following this alloy, quite closely, was No. 20, an alloy very bright in color, almost white, and having a ragged fracture. It was an exceedingly brittle alloy; its average value for θ_r being but 6·8°; its value of T was very good. If this value alone had been considered, it would have entitled it to a much better position; but from a consideration of all the facts it was not thought best to advance its position in the list. The eleventh was No. 16. This was a remarkably dense alloy, very hard, with a fracture closely resembling that of steel. Its values of M were quite high and those for T especially so. B was a finer specimen than A, but the difference was not great enough to warrant the rejection of A. It was very brittle. No. 3, the twelfth alloy upon the list, was slightly less brittle than the preceding, its average value

of θ_r being 11·9°. While testing A a "set" took place and this was the cause of A yielding values so much higher than B and values which are higher than can ordinarily be expected from this alloy. It broke suddenly, giving a very ragged, granular fracture; it was light in color. Thirteenth, No. 17.—This was a very ductile alloy, its values for θ_r averaging 48·6°. It was of a deep golden color, and had a smooth, regular fracture, twisting apart slowly and evenly. The composition of this alloy was very nearly the same as that of the "Tobin Alloy." Fourteenth, No. 19, was a close-grained, brittle alloy, nearly white in color, and gave a very ragged and uneven fracture; it broke suddenly. The values of A alone have been considered, the others being far too low. Fifteenth, No. 9.—This was another very brittle alloy, with a fracture closely resembling that of steel. Sixteenth, No. 6.—This was very ductile, giving a smooth, regular fracture, and breaking slowly and evenly. Its values of M and T were very fair. Seventeenth, No. 12.—This was not a triple alloy, as it contained copper and zinc only. It was an exceedingly beautiful alloy, of a very deep golden color and very closely grained. B was much the finer specimen, though there was not much difference in the values obtained. This was, by far, the most ductile alloy tested, the average of θ_r being 113·3°, though 125° would undoubtedly be a fairer average value. This was a good alloy. Eighteenth, No. 23, was the second most ductile alloy, and one of its values for θ_r was only 3.4° less than the highest values of No. 12; but the other values of this piece, B, have been rejected as being unreliable. This alloy had a fine fracture, smooth and regular. In color it very closely resembled green bronze. Nineteenth, No. 13, was also a dual alloy, and though resembling No. 12 in appearance and giving high values for θ_r, its ductility was only about one-half that of No. 12; this was expected, for the amount of zinc was increased 2 per cent. at the expense of the copper, which made it more brittle. Twentieth, No. 15, was exceeedingly brittle, and closely resembled steel in its fracture. Twenty-first, No. 2.—The results obtained for the piece B—A was thrown out—were not as expected; it was surrounded by alloys which gave much better results and therefore such a weak specimen was not looked for in this place. It was quite ductile and had a good, even fracture; it resembled No. 23 in color. Twenty-second and Twenty-third, Nos. 8 and 14.—These alloys both contained large amounts of zinc and little copper, and consequently, gave but poor results; they were both brittle and

weak. No. 11 contained more zinc than No. 8. These data have been summarized in the diagram and here it is very plainly seen what position each alloy occupies upon the field. It was concluded from the above that the peak of the mountain was at No. 22, and that the field enclosed by the dotted lines, diagram IV, contained all the best alloys. No. 6 was seemingly an exception, standing sixteenth, yet it was included because it was thought that, in a subsequent investiga-

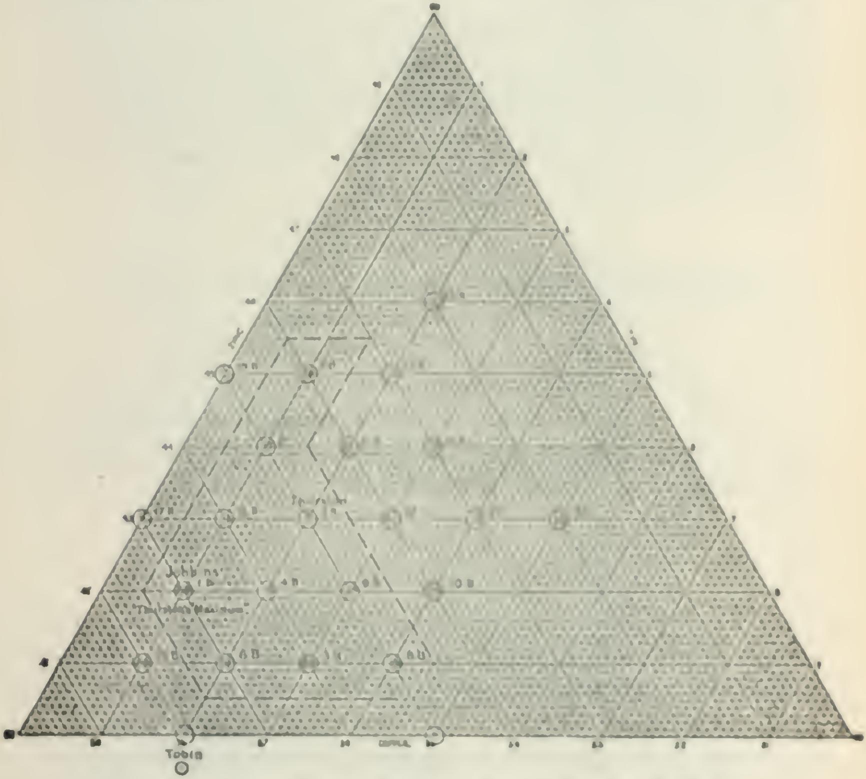

DIAGRAM IV.—LOCATION OF STRONGEST BRONZES.

tion, higher values may be obtained. It was thought doubtful whether, in another test, No. 18 would continue to hold such a high position. After a careful study of this field, the conclusion was reached that within it all is empirical. Though No. 22 was the strongest alloy, yet, for practical purposes, it would always be better and safer to try to obtain an alloy of the composition of No. 6 ; for a slight change in the composition would not be likely to produce a

defective metal; while No. 22 stands upon an edge of the field, and a very slight variation in composition might make a very great change in strength. Therefore, in conclusion, No. 22 is Professor Thurston's "*Strongest of the Bronzes*,"* and No. 5 is the best for practical purposes. These two alloys are respectively, copper 57, zinc 42, tin 1; and copper 56, zinc 42, tin 2. (See Table I.)

It is intended at the earliest possible moment to repeat some of these tests and to verify some of the results; but there is very little probability that any great change will be consequent upon such repetition of the work. No. 22 is marked "Jobbins," on diagram IV and, meantime, may be assumed to be substantially representative of what Prof. Thurston has shown to be, as he states it, the "*strongest bronze that man can make.*"

Thevenin's Theorem.—Let V and V^1 be the potentials of two points, A and A^1, in a system of united linear conductors enclosing electromotive forces E_1, E_2, . . . E_n, distributed in any manner. If the points A and A^1 are united by a wire, ABA^1, of resistance r, containing no electromotive force, the potentials of the points A and A^1 take values different from V and V^1, but the current i, which circulates in the wire, is given by the formula

$$i = \frac{V - V^1}{r + R}$$

in which R represents the resistance of the primitive system, measured between the points A and A^1, considered as electrodes. Thus Ohm's formula is applicable, not only to simple electromotive circuits with poles well defined, but also to any network of conductors, which may consequently be regarded as an electromotor with arbitrary poles, of which the electromotive force is, in each case, equal to the difference of the potentials pre-existing at the two points which are chosen for poles.—*Comptes Rendus*, July 16, 1883. C.

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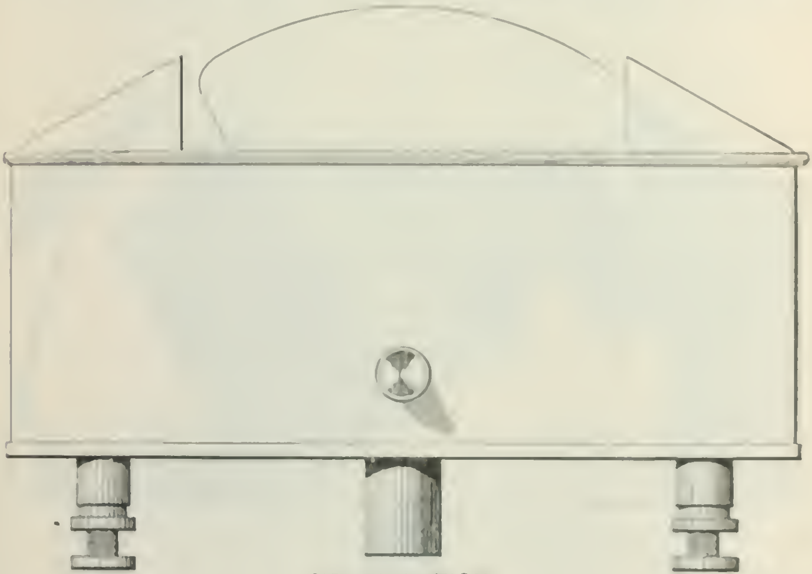
* According to Professor Thurston, this was to be looked for among compositions approximating, copper 55, zinc 43, tin 2; Strongest of the Bronzes.—*Trans. Am. Soc. C. E.*, No. 1, 1881.

A TILTING WATER METER FOR PURPOSES OF EXPERIMENT.

By J. C. Hoadley, Boston, Mass.

Having had to make, in the course of the year, a great number of experiments in pumping water filtered through sand under various prearranged conditions, in quantities ranging from little more than one gallon in an hour to eight or ten gallons in a minute, the writer soon found that all commercial water meters were wholly unsuitable for his purposes. They were liable to obstruction by sand, inaccurate at best, wildly inaccurate at very low speeds, and difficult to read at high speeds. In addition to this, the readings were at all times insusceptible of verification and of permanent record.

Not having found, after search made, any account of a suitable

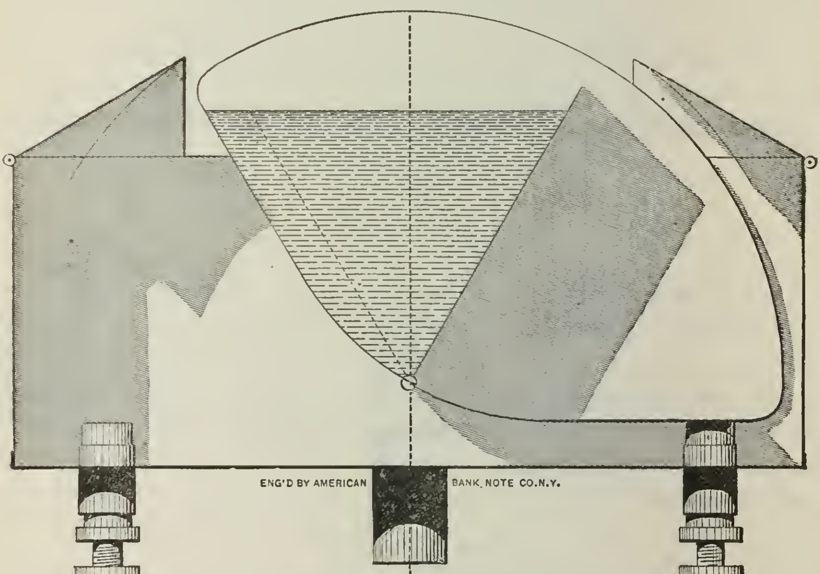


SIDE ELEVATION
SCALE ¼

instrument, it became necessary to devise one, and without presuming that this is wholly new or unknown to all the members of this society, drawings and a description of it are presented as a matter of record for what it is worth.

There was required an instrument which would measure and record with all possible accuracy, and without liability to important error, the quantity of water flowing in a continuous, but pulsating, and sometimes variable, stream, in accurately ascertained intervals of time. As constructed and used the instrument is very simple and inexpensive, and is clearly shown in the accompanying drawings.

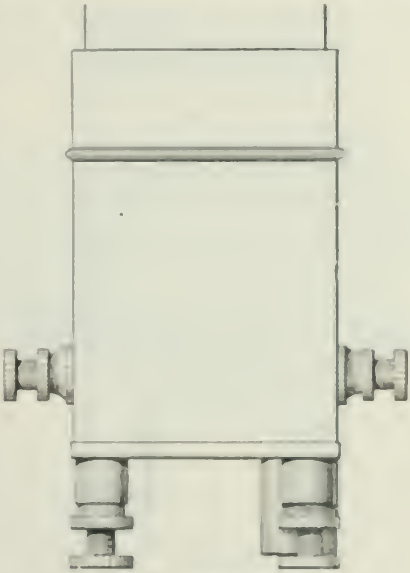
Two **V**-shaped cups, each embracing an angle of 60°, are joined together by a common side, which is, in fact, a mere partition between them, so that the two cups together embrace an angle of 120°. This double cup is supported in a case upon pivots directly under the partition, turning in hollow, adjustable screws in nuts attached to the case, one on each side. When one of the outside plates of the double-**V** cup is in a horizontal position, supported in that position by two cork stops on which it rests, the partition between the two **V**-cups makes an angle of 30° with the vertical, and the outside plate of the upright cup makes an angle also of 30° with the vertical, but at a little greater



LONGITUDINAL, VERTICAL, CENTRAL SECTION
SCALE ¼

distance horizontally from a vertical plane passing through the axis of the pivots, on account of the curve by which the outside plate is joined

to the partition and to the outside plate of the prostrate cup at its lower end. But for this greater horizontal width on the outer side there would be no tendency to tip—the upright cup would simply fill up and overflow, and there would be an end. But as the water rises in the upright cup, the prism of water outside of a plane passing through the axis of the pivots and making an angle of 30° with the vertical, acquires constantly increasing preponderance over the equipoise of the wedge-shaped body of water bounded by planes, each making an angle of 30° with the vertical, and intersecting in the axis of the

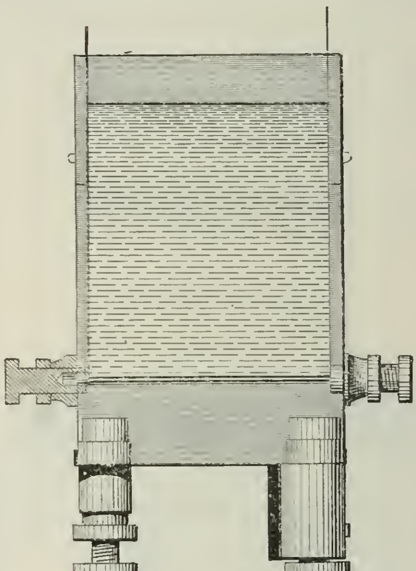


END ELEVATION
SCALE ¼

pivots. When this preponderance becomes sufficient to overcome the mechanical advantage of the prostrate cup itself over the upright cup—an advantage due to its greater leverage with equal weight—the cup will tilt, the water in the upright cup, nearly filling it, will be poured out into the case to run away through its spout, and the now empty cup, lying prone on its cork stops, will become the prostrate cup, with the greater leverage—its center of gravity being at the greater horizontal distance from the axis of the pivot. The other cup, now upright, will be filled in its turn and repeat the tilting process, and so on alternately as long as the stream flows into the cups.

The tip is very sudden, and is made with considerable force. A

light spring of sheet brass attached to the case in the middle of its length by a piece of wood which insulates it is connected by a binding post with one pole of a battery, and the case itself is in like manner connected with the other pole. A bit of sheet brass soldered to the outside of the tilting double cup, directly opposite the partition and above the case, forming a sort of cam, comes into contact with the spring in passing. This completes the circuit interrupted by the block of wood which supports the spring, and records each tip by a dot or



CENTRAL CROSS SECTION
SCALE ¼

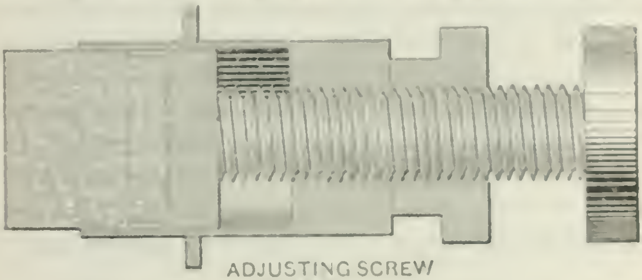
short dash. The cam does not come into contact with the spring until the tilting cup has acquired considerable momentum, so that the tilting is not sensibly retarded.

In designing this instrument the weight per square inch of the sheet tin selected for it was first ascertained. The whole of the double cup, ends, sides and partition lying on each side of a vertical plane, passing through the axis of the pivots, was then divided into simple geometrical figures, the center of gravity of each figure was found, and the horizontal distance of the common center of gravity of each portion from the vertical was computed. The weight of each portion lying on each side of the vertical was also computed, and multiplied by the corresponding horizontal distance of each center of gravity, which gave, of

course, the static moment of that portion of the double cup on each side of a vertical plane passing through the axis of the pivots.

The difference of these static moments was the preponderance of the prostrate over the upright cup—both empty—to be overcome by the water in the upright cup when full to the tilting point, and this was computed in a similar manner. A slight adjustment of the cork stops sufficed to compensate for the inaccuracy of these calculations.

This leads me to speak of the matter of adjustment by means of the cork stops. I actually used a mere socket, like a short candlestick, to hold each cork, entirely inside of the case, which was plain on the bottom. In the drawings will be seen four long sockets, projecting below as well as above the bottom of the case, with adjusting screws and check nuts. The adjustable corks are held in short sockets, with thick



ADJUSTING SCREW
FULL SIZE

bottoms to rest on the adjusting screws, heavy enough to keep the corks from floating away. This device is untried, but I think it quite practicable and no less desirable.

I had two of these meters, substantially alike, and adjusted them by flowing water through them into a tub placed on scales, counting the tips, and taking the weight and temperature of the water. I then placed one of the meters directly over the other, supported upon the tub by a suitable frame, and flowed a stream through both, the electric register recording the tips, and the scales accounting for the quantity of water. The first tip of the upper meter did not fill the lower meter to the tipping point by about $\frac{1}{16}$ inch, a little water adhering to the cup and case of the first meter, but the second tip of the first was instantly followed by the first tip of the second, and so on until the tub was filled. A repetition of this experiment gave substantially the same results—61 tips in 202¾ pounds = 3·33 pounds per tip, and at 80 F., 0·4 gallon per tip—231 cubic inches per gallon.

The electric register also recorded upon the same ½-inch strip of

paper the beats of a seconds pendulum, and, when two pumps were used, the strokes of the pumps and the tips of each meter. It was also easy to note the tips by the ear while watching the second hand of a horse-timer, by which means the interval of time between tips could easily be observed to quarters of a second. This is not an instrument of precision. It is, perhaps, a little more accurate than a gallon measure at all practicable speeds; at slow speeds probably decidedly more accurate, and, with proper care, no considerable error is likely to occur. When operated very rapidly the swaying of the surface tends to accelerate or retard in a small degree the tipping of a cup nearly full, but there is no tendency to accumulation in such errors, which, therefore, may be presumed to balance each other, at least in some degree. The sloping covers at the ends of the case were an afterthought to prevent spattering, and were kept a sufficient distance apart to admit of taking out and replacing the tilting double cups. The curved wings under these sloping cups were a second afterthought for the same purpose, and, as it stands, the case arrests all water—there is no spattering. Of course, a suitable funnel is generally desirable to collect the water from a pump and to convey it into the cup in a stream as steady as possible, and vertically over the axis of the pivots. It is also necessary that the meter should be level, both when adjusted and when in use.

This instrument substantially weighs the water of a flowing stream, and may possibly prove useful, if strongly and delicately made, nicely adjusted and suitably porportioned to the quantity to be recorded, for keeping the record of water used during tests of steam engines and boilers. It is respectfully submitted to the profession for what it is worth.

Distillation of Benzine.—J. Chevalier, a dyer and scourer, of Toulon, employs benzine in cleaning his articles. The benzine soon becomes charged with foreign matters, is discolored, exhales a disagreeable odor, evaporates very slowly and loses its cleansing properties, so that it must be replaced by a new supply. Thinking that it might be possible to make a great saving by distilling the deteriorated benzine, he obtained remarkable results. The distillation gave a product which was limpid, much purer than the ordinary commercial benzine, ten per cent. lighter, and much more efficient in its action.—*Chron. Industr.*, April 8, 1883. C.

CAST IRON IN STEAM BOILERS.

By S. Lloyd Wiegand.

[Read at the Stated Meeting, February 20, 1884.]

Considerable interest having been expressed in the matter of the bursting of a flat boiler head, parts of which were shown at the January meeting of the Franklin Institute, and the limited supply of water having delayed the opportunity of testing the riveted iron drum with flat cast iron heads, as was intended at that meeting, all of the procurable parts of the burst boiler head are here produced, that the members may examine them.

The conditions under which the boiler head burst, have been differently stated by different parties who were present at the accident and both immediately before and thereafter, and the statements made by the same witness of the accident at different times appears to vary.

This is not an unusual occurence in regard to boiler explosions, and that it should be so will, upon a moment's consideration, appear a most probable state of affairs.

The party in charge of a burst boiler, should ordinarily know most about its condition before the accident, such persons are most apt to be killed, in which event their testimony is hopelessly beyond reach, or, if not killed and they are hurt, they are so shocked and astonished that their mental faculties are for the time impaired. But assuming that they are neither killed nor hurt, they are the parties upon whom naturally responsibility for the disaster should at first sight appear to rest and are put on the defensive to make the best showing they can for themselves, and as a rule they do the best they know how to do in that direction.

The explanations offered by boiler attendants, such under circumstances, often broadly suggest and sometimes demonstrate, both their incompetency or their ignorance.

So that after all, in investigating the causes of such disasters, the most reliable parts of the testimony are the pieces of the wreck which after being examined carefully in many cases, prove much of the oral testimony to be entirely inconsistent with demonstrated fact.

That the heads of the vessel we now propose to test may be compared with the burst boiler, which had heads made from the same

pattern, is the reason for the appearance of these parts of the wreck at this meeting.

It was alleged that the exploded boiler was under a pressure of less than 60lbs. per square inch, and that it was in fluid communication with the steam pipe of the other two boilers, which did not burst.

The steam guage of the other boilers was uninjured and proved so upon test by the maker after the accident.

The steam guage of the bursted boiler was burst and destroyed.

One of the proprietors testified, that both the safety valves of the bursted boiler sometimes stuck, and that preceding the accident several witnesses said the steam did not blow off from them.

These valves were set to a higher pressure than the engineer, and other witnesses testified was indicated by the steam guage.

The engineer testified, that there was not over 40lbs. of pressure of steam on the boiler, but that the safety valves blew off right up to the time of the explosion.

This boiler prior to being put in use, had been subjected to a hydrostatic pressure of 115lbs. per square inch.

There was much conflicting testimony taken from employés of the works where the accident occurred—the testimony before the Coroner and his jury, and the testimony given in Court, in a case in which a suit for damages was tried, resulted in a large volume of stenographic reports, which displayed more conspicuously conflicting opinions of professional experts as to the cause of the accident than anything else.

The uncontested facts that appeared were those demonstrated by the parts of the wreck—these we have here.

An endeavor having appeared to commit the Franklin Institute, by a series of ingeniously worded preambles, to a disapproval, or condemnation of flat cast iron heads, as parts of cylindric steam boilers, and the fact, that upon the docket of the United States Circuit Court for this district several cases appear analagous to, if not identical with the one already tried, it seems but proper that the members of this Institute should personally discountenance all attempts to prejudice or pervert public sentiment upon questions in litigation, and that this Institute should limit its operations, as it has heretofore consistently done, to the investigation and accurate ascertainment of exact facts in science and the mechanic arts.

The highest usefulness of this Institute having been heretofore achieved in promoting the mechanic arts and sciences (for which

purpose alone it has been chartered), by imparting reliable information and giving satisfactory reasons therefor, it is respectfully suggested that a departure from such practice and the substitution of mere opinions, unsustained by substantial and conclusive evidence and expressed either in preambles or resolutions, is both undesirable, and in defeat of the purpose of our organization and charter.

STANDARDS OF LENGTH AND THEIR SUBDIVISION.

By GEORGE M. BOND, Hartford, Conn.

[A lecture delivered before the FRANKLIN INSTITUTE, February 21, 1884.]

We are all, no doubt, familiar with the old table of English measures of length beginning "3 barleycorns make one inch." I, for one, can remember having vague ideas in regard to barleycorns in general, and their exact size in particular, though I imagined I knew exactly what constituted an inch. Later in life I began to doubt my knowledge in this respect, having had considerable difficulty in reconciling the differences between two separate inches not exactly alike, one or both evidently not $\frac{1}{36}$ part of a standard yard.

It may be of interest to glance over the history of the gradual development of the modern science of minute measurement; to notice how such crude standards as the human foot or arm, and standards called cubits, fathoms, or the foot made up of "36 barleycorns, round and dry, placed end to end," in the course of time grew into the more exact determinations of scientific research, as shown in the results of the labors of men like Kater, Baily, Bessel, Sheepshanks, Shuckburgh, and Sir George Airy in the great problem of establishing a standard of length from a natural unit. They gave us so closely the relation of the length of a pendulum beating seconds of time to the length of a yard, that it was thought they had determined, beyond further doubt, the means for restoring a lost standard should it become necessary to do so from any cause.

However good these crude standards, such as a barleycorn, a human arm or foot may have been for practical purposes at the time they were adopted, they certainly are in our times completely out of the question and useless for precise determinations. As all measures derived from them were purely arbitrary, and sanctioned by law, no reference made

to any of these sources could be presumed to restore a lost original standard, even such as a common yard-stick, except within a very liberal margin of error, we need not be surprised then to find that there happened such wide ranges of value for a foot as that of the Pythic of $9\frac{3}{4}$ inches to that of Geneva of 19 inches.

The adoption of an invariable unit as a standard of length, while seemingly only applicable to the refined methods of science, really becomes a necessity in our ordinary workshop practice, as we shall see later.

The arm of King Henry the First, or the barleycorn, though possibly furnishing a standard good enough at that time, would hardly satisfy the requirements of our modern mechanics or tool makers, who work very often within the limit of a thousandth of an inch, and even *one-tenth* of this apparently minute quantity, with surprising unconcern and no less accuracy.

To the celebrated philosopher and scientist Huyghens, is due the honor of having demonstrated the fact, that the times of the vibrations of pendulums depend entirely upon their length. About the year 1670, his inventive genius conceived the plan of using this fact to establish the length of a standard which should be the unit for measures of length. This he divided into three equal parts, each of about 13 inches, calling this third part the "horary foot."

Picard, in 1671, also proposed using the length of a pendulum beating seconds of mean time, which should be adopted as the unit of length, thus endorsing the plan of Huyghens. It was Picard who first measured the arc of the meridian from Paris to Amiens in 1669, deducing from it the value of a degree to be 68·945 miles. Picard was the first to suggest that the diurnal revolution of the earth necessarily affected the times of oscillation of a seconds pendulum, and that it ought to vibrate more rapidly at the poles than at the equator. His experiments at different latitudes, however, failed to confirm this fact, probably owing to the lack of sufficiently accurate apparatus for his work, and it was left to Richer, in the same year, 1671, to prove that at the equator, or 4° 56′ north, where the observations were made, the difference of the length of a seconds pendulum at that place, as compared with the length at Paris, or 48° 50′ north, was about a line and a quarter, or nearly one-tenth of an inch.

Cassini, in 1718 proposed a unit which should be $\frac{1}{6000}$ part of a

minute of a degree of a great circle of the earth, and which would be nearly equal to a third part of our yard.*

M. de la Condimine, who had measured a degree at the equator in Peru, in a Memoir read before the Academy of Sciences at Paris, advocated the use of a pendulum as the unit of length, proposing that it should beat seconds at the equator, a place least likely to cause prejudice that might follow from national jealousy, were the latitude of any particular place selected.

Talleyrand, in 1790, proposed to the Assembly of France that a commission be appointed to consult with a similar commission from the English Government, to consider the subject of a uniform international system of metrology. He favored the length of a pendulum as compared with the unit obtained by the subdivision of a quadrant of the earth's meridian, but after a careful consideration of the three plans proposed: the pendulum, a quarter of the equator, and a quadrant of the earth's meridian, they concluded to recommend the latter method.

In 1790, one year before the International Commission had adopted the ten-millionth part of the quadrant, as settling the question of a natural unit for a standard measurement of length, and before any steps had been taken by them in the matter, Thomas Jefferson, then Secretary of State, in obedience to a resolution of Congress calling upon the Secretary to propose a plan for establishing a uniformity in the currency, weights, and measures, for the United States, recommended, in his report, a decimal system of metrology, and that the unit be derived from a natural and invariable standard of length.

Jefferson considered that though the globe or its great circles might be invariable, the means to be employed to obtain an accurate subdivision of a quadrant, from previous trials, had showed their unreliability, and promised too great a degree of uncertainty; he also objected to the ordinary form of the pendulum as "not without its uncertainties," the length not being possible to be accurately determined, owing to variations in the clock-work mechanism and the barometric and thermometric variations. He recommended the latitude of 45° and a mean temperature of the year at that location.

Instead of using the ordinary pendulum of 39 inches, he advised the use of a seconds rod of 5 feet, known as Leslie's pendulum rod.

* Report on Weights and Measures, by Dr. Alfred B. Taylor, Eighth Annual Session, Pharmaceutical Association, Boston, September 15, 1859.

This was a simple straight bar, without a disc or bob, suspended at one end, and free to swing at that point, its centre of oscillation being at a distance of two-thirds of its length from the point of suspension. It would be one-half longer than the ordinary loaded pendulum.

A rod of this kind, vibrating seconds, is 58·72 inches long.

He proposed that this rod be made of iron, of such a length that at the level of the sea, at a latitude of 45°, and with a constant temperature, it should beat seconds of mean time; its length, given exactly, would be 58·72368 inches.

Jefferson then proposed dividing this length into 5 equal parts, calling each part a foot, which would give 11·7449 inches as the length of the new foot. He then divided the foot into 10 equal parts, affording a decimal subdivision to correspond with the decimal character of the coinage of the country.

The French Commission, after carefully determining the length of a quadrant of the earth's meridian, and dividing it into 10 million equal parts, presented science and the world with the meter as a universal standard to which posterity might ever afterward refer.

Its length, as they computed it, is very nearly the length of the seconds pendulum, or 39·370788 inches, or a little more than 3 inches longer than the yard.

This meter, which is an end measure standard, was made of a pure alloy of platinum and iridium, 90 parts of the former to 10 of the latter. It is called the "Mètre des Archives," and is kept in the buildings of the International Bureau, at Breteuil, between Paris and Versailles.

Having thus briefly touched upon the history of individual and national efforts to secure a unit for a standard of length, covering a period of about 200 years preceding the legal adoption of our standard yard, it may be interesting to know that just 500 years after the statute of 17th Edward II, A. D. 1324, which enacted that "three barleycorns, round and dry," make an inch, and 12 inches make one foot," it was, by act of 5th, George IV, Cap. 74 (1824), that a legal definition of the yard was made, and by it was declared that the yard-bar, made by Bird in 1760, should be the standard beyond any question or doubt.*

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* This Act was introduced into the House of Commons in 1822, but failed to pass the House of Lords. It was again introduced, with modifications,

It may be in place to quote here an abstract of the Act of June 17, 1824, legalizing this standard, and which reads as follows:

SECTION I. Be it enacted .....that from and after the first day of May, one thousand eight hundred and twenty-five, the Straight Line or Distance between the Centres of the Two Points in the Gold Studs in the Straight Brass Rod, now in the Custody of the Clerk of the House of Commons, whereon the Words and Figures "Standard Yard 1760" are engraved, shall be and the same is hereby declared to be the Extension called a Yard; and that the same Straight Line or Distance between the Centers of the said Two Points in the said Gold Studs in the said Brass Rod, the Brass being at the temperature of Sixty-two Degrees by Fahrenheit's Thermometer, shall be and is hereby denominated the "Imperial Standard Yard." * * *

SECTION III. And whereas it is expedient that the said Standard Yard, if lost, destroyed, defaced, or otherwise injured, should be restored to the same Length by reference to some invariable natural Standard; And whereas it has been ascertained by the Commissioners appointed by His Majesty to inquire into the subject of Weights and Measures, that the Yard hereby declared to be the Imperial Standard Yard, when compared with a Pendulum vibrating Seconds of Mean Time in the Latitude of London in a Vacuum at the Level of the Sea, is in the proportion of Thirty-six Inches to Thirty-nine Inches and one thousand three hundred and ninety-three ten thousandth Parts of an Inch; Be it therefore enacted and declared, That if at any Time hereafter the said Imperial Standard Yard shall be lost or shall be in any Manner destroyed, defaced, or otherwise injured, it shall and may be restored by making a new Standard Yard, bearing the same proportion to such Pendulum as aforesaid, as the said Imperial Standard Yard bears to such Pendulum.

Just 10 years afterward, Oct. 16, 1834, occurred the calamity for which the carefully worded text of Section III was intended to provide; a contingency certainly most wisely considered. This was the

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in 1823, but was not passed until June 17, 1824, to go into effect as stated, May 1, 1825. This was however postponed to January 1, 1826.

["Weights and Measures," by Prof. F. A. P. Barnard, Johnson's New Cyclopaedia, p. 1737, Appendix. See also Encyclopedia Brittanica, 8th Edition, Vol. xxi., pp. 803 and 807.]

destruction of the Standard Yard by fire, when both houses of Parliament were burned.

The bar was recovered, but in a damaged condition, and all hopes of restoring its usefulness were abandoned, when it was found that one of the gold plugs had been melted out. The provisions of the Act now came into service, in order to reproduce the lost Standard, and it became necessary to decide whether it could be restored by the use of the method so carefully prescribed.

It had been proved conclusively since the passage of the Act that there were errors in the determination of the specific gravity of the pendulum employed; the reduction to the sea-level had been shown by Dr. Young to have been doubtful, the reduction for the weight of air was also proved erroneous, and Kater showed that sensible errors had been introduced in comparing the length of the pendulum with Shuckburgh's scale, this bar having been compared with Bird's "Standard, 1760," and found to agree closely.

Shuckburgh's scale was marked ($0 — 36^{in.}$), and was made by Troughton, in 1798, and had been compared with the pendulum and with the meter. It may be interesting to know, that as previous to Shuckburgh, all transfers of the yard were made by the use of beam compasses, and comparisons were also made in the same way.

It was not until 1798 that optical instruments were used for this purpose, and Troughton must be credited with having introduced this wonderfully improved manner of dealing with minute measurements, and which afterward, no doubt, led to the discovery of the errors found to have crept in when the relation of the yard to the length of the pendulum was established.

All attempts, therefore, to use the pendulum for the purpose of reproducing the lost standard were abandoned. The next step was to approximate this result by the use of standards then in existence, which had been compared with the original yard.

The bars used for this purpose were:

(*a*) Shuckburgh's Scale ($0 — 36^{in.}$).

(*b*) Shuckburgh's Scale, with Kater's authority.

(*c*) The Yard of the Royal Society, constructed by Kater.

(*d*) Two Iron Bars, marked A_1 and A_2, belonging to the Ordnance Department, and kept in the Office of the Trigonometrical Survey.

To Sir Francis Baily was intrusted the work of the restoration of the yard. His death occurred in 1844, before the work was completed.

He had then only completed the provisional or preliminary investigations necessary for this most important undertaking.

He had, however, made a great many experiments to determine the proper material for the new standard, and finally decided upon the alloy of which Bronze No. 1 was afterwards made. It is still known as Baily's metal. Its composition is copper 16, tin 2½, and zinc 1.

The work was now entrusted to the Rev. R. Sheepshanks. He constructed first, a brass bar as a "working standard." This bar was compared with all the standards considered by him necessary for the purpose, and which were those just mentioned. Taking the average of all the values of each as compared with the brass bar No. 2, as the working standard was designated, and reducing to an assumed value of the original standard yard, he found as the relation of the new yard, brass bar 2 = 36·00025 inches of the lost Imperial standard, taken at 62° F. The brass tubular scale of the Astronomical Society did not appear in the list of bars used as references (see Phil. Trans. 1857, p. 661), and the statement that this was the principal authority for the new standard is therefore incorrect.

Bronze 19, as the new yard was designated, or now known as No. 1, was graduated according to this value, in terms of the lost Imperial standard, found from the comparison of these five standards, and is made, as just stated, of Baily's metal, the dimensions are: length 38 inches, depth 1 inch, width 1 inch. The graduations are upon gold plugs inserted in wells of such a depth as to bring the polished surface of the plugs at a distance from the top, one half the depth of the bar, the plugs being 36 inches apart.

The bar which is now before you is a copy in every respect, except that it has the subdivision of feet besides; but we have the same material, the same dimensions, and the same conditions in the graduations, while more than all, the distance between the two defining lines as compared with Bronze No. 1, varies less than one hundred thousandth of an inch at 62° F.

This bar was constructed by Prof. W. A. Rogers, of Harvard College Observatory, Cambridge, for the Pratt & Whitney Company of Hartford, Conn., for their use as a final reference standard. It has been compared directly with Bronze 11, at the office of the Coast Survey, by Prof. J. E. Hilgard and Prof. Rogers, and allowing for the known relation between Bronze 11 and Bronze No. 1, its value was found to be within this minute limit, in terms of the Imperial Yard.

The reason assigned for placing the lines at the centre of the depth

of the bar, was that errors arising from *flexure* were liable to occur; that is, by the bending of the bar, the distance between the lines becoming less. Having the graduations at the centre was thought would neutralize this effect. We all know that if a beam is supported at the ends and loaded in the middle, the beam is compressed at the top, and stretched or extended at the bottom, and if we were to measure between finely drawn lines, before and after the load was applied, we would find that the lines were nearer together when the beam was under strain than when free, measuring, of course, in a straight line, so it was thought that having the lines midway between the top and bottom of the standard bar, this error would be reduced.

Captain Kater was the first to discover the variations due to the flexure of standard bars upon which graduations were traced, and he first proposed a "neutral plane," which would have the effect, within certain limits, of reducing this error to zero. He first located this plane in the centre of the bar, as was done in the case of the Imperial Yard, but from further investigations he concluded that it was not quite one-third the thickness of the bar below the graduated surface.

He found that the errors from the effect of flexure depended upon the thickness of the bars compared with each other, and when resting upon a surface which is not plane (Phil. Trans. 1830). He also found that this error far exceeds that which would arise from the difference of the length of the arc and its chord under the same circumstances; so much so, that in a bar an inch thick, with the versed sine, that is the distance at the centre of the bar from the horizontal plane joining the two ends to the curved surface, equal to one hundredth of an inch, the sum of the errors would be nearly one thousandth of an inch in the length of a standard yard. To overcome the objection of a variable result at every position of a standard bar, the number of supports for it has been carefully determined, and in the case of the Imperial Bronze 1, the number of these supports is eight, and having been decided by Mr. Baily to be necessary, this was adopted for the national standards. The distance between the supports is about $4\frac{1}{2}$ inches.

Sir George Airy gave a formula for determining the distance between the supports for any standard bar, in order to neutralize the effect of flexure. It is

$$\frac{\text{Length of the bar,}}{\sqrt{n^2 - 1}}$$

"n" being the number of supports.

In the bar we now have before us, the conditions under which it was transferred, and also when investigated, was when resting upon *two* supports, and using the formula just given, the distance between them is about 22 inches, the total length being 38 inches. You will notice it places the supports a little less than one quarter the length of the bar measured from each end. This gives the surface a certain permanence or equilibrium of position when resting upon any *level* surface, whether a true plane or not, and if used thus under the same conditions of temperature, the distance between the defining lines remains the same. If we move the supports each nearer the ends, say an inch and a half, the surface changes slightly, and the result is to bring the lines at the end nearer together, as we have mentioned before.

According to the Report of Prof. J. E. Hilgard, Chief U. S. Coast and Geodetic Survey, in charge of Verification of Standards, in 1877, Bronze No. 1 is kept at a very uniform temperature within the walls of the Houses of Parliament, while Bronze No. 6, which is the accessible national standard, is preserved in the Strong Room of the Old Treasury, now No. 7, Old Palace Yard. There is not now any perceptible difference between these two Standards.

The Imperial Yard is in charge of Dr. Chaney, his official position being Warden of the Standards.

In order to secure, as far as possible, accurate duplicates of the new standard, four Parliamentary copies were constructed, one of which is kept in the Royal Mint, one is in charge of the Royal Society, one is preserved in the new Westminster Palace, and the other is kept at the Royal Observatory at Greenwich.

There were also 40 copies made of Baily's metal for distribution among the different governments, only two of these 40 bars are exactly standard at 62° F., these are, Bronze 19, and Bronze 28. Both are kept at the Royal Observatory for reference, as representing the national standards. All the other copies have a certain relation to Bronze 1, and instead of giving this relation, the temperature at which they are standard is established for each.

The standards prepared by Mr. Sheepshanks were legalized by Act of Parliament, June 30, 1855, and in 1856 Bronze 11, one of the 40 copies made of Baily's metal, was presented to the United States Government by the British Board of Trade, and was standard at 61·79 degrees Fahrenheit. This bar is deposited in the office of the

United States Coast Survey at Washington. It has since been found that Bronze No. 11 is *shorter* by 0·000088 of an inch at 62° F. from comparisons made by Prof. J. E. Hilgard, in charge of the Bureau of Weights and Measures, United States Coast Survey, who, in 1878, compared it directly with the Imperial Yard at the British Standard Office in London, and consequently, to be standard, must be considered so at 62·25 degrees Fahrenheit.

Previous to 1856, the distance between the 27th and 63d line of the brass scale made by Troughton, was taken as standard, though never having been legalized by Act of Congress, it had an indirect authority, as it was adopted by the Treasury Department, and copies of it were made for distribution among the different States under the charge of Mr. Joseph Saxton.

The fact is noticeable that all the copies of the Imperial Yard are made of the same material as that of the original Bronze 1. This is no doubt owing to the greater uniformity in the coefficient of expansion for each standard bar, admitting of comparisons at any temperature. This would not be possible, except for bars of other metals whose coefficient or rate of change for each degree of temperature was definitely known, and this would make it an exceedingly nice operation.

To illustrate this in a few words. If a steel bar or a platinum standard be compared with one made of brass or Baily's metal, and each were standard only at 62°, if we should compare them at 72° we would find them not alike in length, because brass expands more for each degree of rise of temperature than does the steel or the platinum; the difference would be greater in the comparison of platinum with the brass standard, as steel and brass have a coefficient more nearly alike.

Let us now briefly refer to what has been done to fix permanently the metric standard of length. The metric system is represented in Great Britain by two bars made of platinum, one being a line measure, and the other an end measure standard.

These bars are of the following dimensions:

Line Metre................	Length	41·000	inches.
	Breadth	1·000	"
	Thickness	0·211	"
End meter..	Length	39·37 +	"
	Breadth	1·000	"
	Thickness	0·287	"

The defining lines nearly traverse the face of the bar for the line meter, and arrows, arbitrarily placed, indicate the position on the lines when measurements are to be made.

The line meter has the words "Royal Society, 45" engraved on the under side. The end meter, being made of so soft a material as platinum, is at present not in a condition to use as a standard for very accurate work, the edges of the end surface being indented and other signs of change in the surface being visible. The end meter has the words, "Mètre à Bouts" engraved on one side, and "Fortin à Paris, Royal Society, 44," on the other. These bars, together with the original standard prepared by Hassler in 1832, are the only recognized standards which have been compared directly with the "Meter of the Archives," as the French standard is called.

The Meter of the Archives is also made of platinum, the dimensions being about the same as the metric standard in London, and this bar was made a legalized standard after all attempts to make it conform to a natural unit were abandoned. It is standard only at 0° Centigrade, or 32° Fahrenheit. Thus we see, that after all, the actual use of a natural unit for creating and reproducing a standard of length was not realized; and standards, made standard by law, were really the final result.

It has been said that "a mystery is a truth hid behind some other truth, and about which the latter throws a veil," and it would seem as if this definition might apply to the great difficulties met with in the attempts to obtain a standard of length from natural laws, and natural conditions, using the grand truths which are known and accepted, but which seems to throw just enough uncertainty around the truth sought, as to make the results doubtful for the purposes for which they are intended. Truth is *exacting*, it allows for no "errors of observation" or of "personal equation," and in no other kind of investigation does this requirement seem more difficult to be fulfilled, as so many "variables"—to use a mathematical term—enter into the problem; variations of temperature, internal strain, due to position of the bar; errors of curvature, errors of observation in using optical instruments; differences in material or of density, thus affecting the rate of expansion or contraction, and a score of other variables, all tending to make the problem a complicated one. We cannot fail to realize—at least partially—the wonderful skill and patience necessary to conduct the experiments which gave us, as English speaking people, the Standard Imperial

Yard, and which 50 years ago were engaging the attention of some of the greatest minds the world has ever known.

There is still another natural unit that has been proposed as a standard of length. This is the length of a wave of monochromatic or single color light.

We have all seen the beautiful colors so wonderfully arranged in the thin film of a soap bubble. These colors are caused by what is termed "interference." To briefly explain this kind of interference, we should know that light is made up of seven distinct colored rays, which blended together produce clear white light. Each of these separate rays of color has an undalatory or wave motion through space, and the length of a wave, or the distance from the crest of one wave to the top of the next, is different for each as compared with unlike color, but constant for its own; that of the green ray, for instance, being computed as being about $\frac{1}{50,000}$ of an inch from crest to crest.

When light is reflected from the two surfaces of the thin film of a soap bubble to the eye, a portion of it must evidently travel a distance twice the thickness of the thin film of the bubble, as part is reflected from the outer and part from the inner surface of the film. The particular ray which must thus travel farther, loses a half of a wave length in the reflection, so that when these two portions of the reflected light come into the same path again, there is more or less interference, and if the retardation has been such that the wave crest of one falls into the trough of the other, they completely neutralize each other, and the corresponding color rays are destroyed. Without attempting the mathematical discussion of this subject, we know that when this relation happens more or less coincident, the rays are either deadened or are so blended that they form the beautiful rings or bands so often noticed. As the film of the bubble changes in thickness, these colors are rearranged, as different sets of color rays or waves are deadened and as different colors disappear from the reflected light.

This unit, no doubt, could be relied upon to produce a standard within certain small limits, but the addition or multiplication of such minute units for the purpose of obtaining a practical standard of length might introduce errors in the total greater than would be likely to result from either of the methods already mentioned.

The use made of this unit seems to confirm the theories in regard to the limit of divisibility of matter, and these same soap bubbles which

are such a delight to children—and we might include some of the older people too—have shown a way in which to estimate, in a purely scientific manner, the dimensions, approximately, of a molecule, a form of matter so minute that the smallest object visible under a powerful microscope is made up of countless numbers of them.

It has been demonstrated that the mechanical energy required to pull apart the molecules of water in forming steam, is no greater, according to the theory of capillary action, than is required to reduce the thickness of a film of water to the $\frac{1}{500,000,000}$ of an inch; a force quite large when compared with the small amount of water which we are considering. The measurement of this minute thickness is based upon the varying colors, using the length of any given wave. Probably before this extreme tenuity could be attained, there would remain only a single layer of molecules held together by their mutual attraction, giving as the estimated average diameter of a molecule the $\frac{1}{500,000,000}$ of an inch, a dimension so infinitely minute as to be quite beyond our ability to realize.

Sir William Thomson, from a comparison of these phenomena, has estimated the limits or range of size of these minute molecules to be between $\frac{1}{250,000,000}$ and $\frac{1}{5,000,000,000}$ of an inch, and in order to give some conception of the "coarse-grainedness," as he calls it, thus indicated, he has said, "that if we conceive a sphere of water as large as a pea, magnified to the size of the earth, each molecule being magnified in the same proportion, the magnified structure would be coarser grained than a heap of small lead shot, but less coarse grained than a heap of cricket balls."

We can thus faintly begin to grasp the idea of the infinite divisibility of matter, and the science of exact measurement of length must stop far short of this limit, as it does far short of the limit of infinite extension.

We have now seen how difficult has been the work of obtaining a standard for final reference, and as it must certainly be supposed to remain an invariable or fixed length after having been once established, great care must be taken to preserve this standard from injury, caused either by wear or oxidization, or change of form.

The materials available for standards of length, taken in the order of their rate of expansion under the same conditions of temperature, are wood, glass, platinum, gold, silver, iron, brass and copper. Wood may be rejected at once for our purpose, though it does very well for

yard-sticks and pocket-rules for everyday use. Glass has been, and is now, used in certain cases, though its great brittleness makes its use restricted and the changes going on within its structure are now the subject of rigid investigation, requiring time to prove its value as a material for standards.

Platinum, alloyed with about 10 per cent. of iridium, is used for the Meter of the Archives, and also for the bars representing the line and end meter standards in Great Britain, to which reference has already been made.

Gold and silver may be said to be excluded for various reasons, that of cost in the case of gold, and its extreme softness, and silver, because of its great affinity for sulphur, which is always present in the atmosphere of cities, forming the dark sulphide that would soon ruin it for use as a standard. There is, however, a silver centimeter scale, ruled by Brunner, of Paris, subdivided into 100 parts, in the office of the Coast Survey at Washington.

Iron bars were used by the French Commission, four standards being made of this material, with polished ends. From one of them was constructed the platinum Meter of the Archives. One of these bars, the only one known to be in existence, bearing the stamp of the Commission, is now in the possession of the United States Coast Survey at Washington.

The Russian standard of length, used for geodetic surveys, was constructed of iron, using conical pieces of tempered steel in each end. This bar has a length of seven feet.

We have already noticed how largely brass, or Bailey's metal has been used for our standard yard, and for the numerous copies made of it. There remains only a brief mention of standards made of copper. M. Tresca, Acting Director of the Conservatory of Paris, constructed a copper line meter of a form which he proposed. This bar is X shaped, very light and strong, and has the lines ruled on a plane midway between the top and bottom edges.

The method adopted at the Conservatory in Paris for comparing the platinum line meter bar with the end "Mètre des Archives" is the use of a plate having the same thickness as the meter, to which is attached a thin piece of platinum terminating in a sharp point. As a statute law forbids contact of any kind whatever in the use of this platinum end meter, the reflection of this sharp point upon the surface of the end of the standard gives the means of observing

the instant of contact without contact being actually made. It is the opinon of M. Tresca that the error can be in this way reduced below 1 mikron = ·001$^{mm.}$, or about $\frac{1}{25,000}$ of an inch, in the transfer to line measure.

(To be concluded.)

ECONOMY OF COMPOUND ENGINES.

By William Dennis Marks,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

(Concluded from page 18.)

It has been shown that the ratio of volume of the cylinders of a compound engine is a function of the ultimate expansion of the steam under the conditions that the power of the cylinders is equalized, and that no drop be permitted in the steam pressure during its course through the engine.

Table of ratios of cylinders and of points of cut-off in non-condensing cylinder and for ultimate expansions of steam.

$$\text{Criterion}\quad \frac{2R \log. R}{R-1} = \log. 2{\cdot}7183\, E$$

$$e = \frac{R}{E}.$$

Ratio of cylinder volumes.	Ultimate expansion of of steam.	Point of cut-off in non-condensing cylinder.	
R	E	e	REMARKS.
$1\frac{1}{4}$	3·426	0·37	These computations are made for general guidance only, nearly all the assumptions made being impossible of exact realization. It is assumed that a perfect gas is used expanding isothermally, that there is no back pressure on the condensing cylinder piston, and that there are no clearances or receiver, and further that there is no cut-off at all for the condensing cylinder, that only being demanded to provide for receivers and clearances in actual practice, and that the cranks are together, or 180 degrees apart.
$1\frac{1}{2}$	4·190	0·35	
$1\frac{3}{4}$	5·015	0·34	
2	5·886	0·34	
$2\frac{1}{4}$	6·813	0·33	
$2\frac{1}{2}$	7·801	0·32	
$2\frac{3}{4}$	8·840	0·31	
3	9·933	0·30	
$3\frac{1}{4}$	10·961	0·30	
$3\frac{1}{2}$	12·277	0·28	
$3\frac{3}{4}$	13·580	0·28	
4	14·882	0·27	

It is useless to carry this table farther. Enough has been done to show the error of exaggeration of ratio, into which designers have fallen, when it is necessary to equalize the power of cylinders and to avoid an intermediate drop for the sake of economy.

Indeed in all engines it will be found that economy of steam as well as smoothness of action, demand that no sudden changes of pressure shall be permitted, and therefore it will be found advantageous in single cylinder engines where clearance cannot be indefinitely reduced to use enough compression to bring the back pressure up to the initial pressure, and so as not to permit an *explosion* in the cylinder at the beginning of each stroke.

The less the clearance the less the compression required for this purpose, and consequently the less the power of the engine is absorbed in fulfilling this condition.

We see, therefore, that clearance is particularly injurious where vacuums are very perfect, and every means should be used to reduce it.

On the other hand, if convenient, very considerable clearances may be used in non-condensing engines provided it is met by a proper increase in the size of the cylinders to compensate for reduction of power and a proper compression is used.

When compound engines must be frequently started or reversed it is important that they be so arranged as to avoid getting on their centres; this does not apply to pumping engines, or indeed to the majority of stationary engines, but does apply with a great deal of force to marine engines.

Some designers have endeavored to obviate this difficulty by placing the cranks 160 degrees apart, thus enabling a very small dead space between the cylinders and obviating trouble with the engine on its centre.

This case differs so little from the case already considered with the cranks together, or 180 degrees apart, that it requires but one precaution on the part of the designer.

The non-condensing cylinder should exhaust *before* the condensing cylinder takes steam, not after, as that would cause a sudden rise in the pressure of the condensing cylinder with the attendant loss.

A good deal of weight is laid on equalizing stresses by placing the cranks 90 degrees apart, but as a very large number of engines of the first type have been successfully designed, there is no reason to believe it impossible in the future to use engines with cranks 180 degrees apart.

It is quite possible to give sufficiently large clearance spaces in the case of engines with cranks at right angles to fulfill to a large extent the functions of a receiver, but it is more economical to reduce the clearances of the the steam cylinders as much as possible and to provide a receiver of proper size. Since this will avoid sudden changes in pressure and the consequent loss.

In what follows we will neglect the variation of the piston's positions due to the angular position of the connecting rods.

Assuming the engine to have obtained its regular movement we will have $P_r = \frac{eP_b}{e_1 R}$ (1)

(See JOURNAL FRANKLIN INSTITUTE, January 1884.)

The sequence of exhaust from non-condensing cylinder, and of cut off of the condensing cylinder, renders necessary the presence of a receiver or its equivalent when cranks are at right angles. The exhaust from the non-condensing cylinder occurs just as the piston of the condensing cylinder reaches mid stroke, and so in order to avoid a sudden change of pressure and of the progress of expansion in the condensing cylinder, it is necessary that its cut off be earlier than one-half stroke.

The size of the receiver only determines the fluctuation of the pressures in it. The smaller the receiver the greater the fluctuations.

It is obvious from what has already been shown that at the instant of cut off of the condensing cylinder, the pressure in it and also in the receiver, as well as the back pressure in the non-condensing cylinder equals P_r.

At the instant of reaching the end of the stroke of the non-condensing cylinder it voids into the receiver its steam at a pressure eP_b.

If we wish this event to occur with as little disturbance as possible we must make the pressure at that event equal in non-condensing cylinder and receiver.

The cranks being at right angles have certain definite positions with regard to each other at all times, and the position of one piston being fixed that of the other can be deduced. If now we assume the cut off e_1 of the condensing cylinder to be $\frac{1+l}{2}$ it will be coincident with the exhaust of the non-condensing cylinder, and the equation

$$P_r = \frac{eP_b}{e_1 R}$$

becomes $e_1 = \frac{1}{R}$ that is $R = 2$, very nearly.

The exit from the receiver to the condensing cylinder being closed, the piston of the non-condensing cylinder now presses back the steam in that cylinder and the receiver until it has reached half stroke, when the pressure is a maximum P_m, we can write the following equation

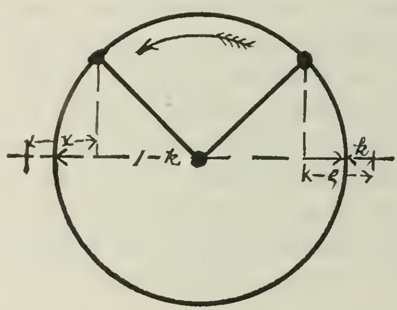
$$eP_b\left(V_n + V_r\right) = P_m\left(\frac{1+k}{2} V_n + V_r\right) \tag{2}$$

In this equation we can fix P_m and determine V_r or vice versa.

In general we can say that e_1 must be somewhat greater than $\frac{1}{R}$ in order to receive the exhaust steam from the non-condensing cylinder without forcing it back.

If we assume that the terminal pressure of the non-condensing cylinder must equal that in the receiver at the moment of opening

FIG. 1.



communication. We can write the following equation, in which $x =$ the distance of the non-condensing piston:

$$P_r\{xV_n + V_r\} = eP_b\,(kV_n + V_r) \tag{3}$$

$$x = \frac{1+k}{2} - \sqrt{e_1(1+k) - e_1^2 - k}$$

We have then

$$\frac{V_r}{V_n} = \frac{e_1Rk - \frac{1+k}{2} + \sqrt{e_1(1+k) - e_1^2 - k}}{1 - e_1R} = r \tag{4}$$

At the instant of cut off a quantity of steam is left in the receiver and non-condensing cylinder at a pressure P_r. As the cut off e_1 is assumed earlier than half-stroke we can then write the following equation.

$$P_r(xV_n + V_r) + eP_bV_n = P_m\left\{V_r + \frac{1+k}{2}V_n + kV_c\right\}$$

The two indeterminate quantities in this equation are P_m and V_r, either of which can be fixed and the other deduced. It will be observed that the clearance of the condensing cylinder is included and therefore that P_m is the pressure at the instant the piston of the condensing cylinder is at the end of the stroke its valve being assumed to have lead and a perfect vacuum to be obtained.

Neglecting the clearances in the cylinders, we have:

$$\frac{[\frac{1}{2} + \sqrt{e_1 - e_1^2}]V_n + V_r}{e_1R} + V_n = \frac{P_m}{eP_b}\left\{V_r + \frac{V_n}{2}\right\} \qquad (5)$$

or

$$\frac{[\frac{1}{2} + \sqrt{e_1 - e_1^2}] + r}{e_1R} + 1 = \frac{P_m}{eP_b}(r + \tfrac{1}{2}) \text{ therefore}$$

$$r = \frac{\frac{P_m}{2eP_b} - \frac{[\frac{1}{2} + \sqrt{e_1 - e_1^2}]}{e_1R} - 1}{\frac{1}{e_1R} - \frac{P_m}{eP_b}} \qquad (6)$$

This can be compared with equation (4) clearances neglected which places the condition of no drop.

$$r = \frac{\sqrt{e_1 - e_1^2} - \frac{1}{2}}{1 - e_1R} \qquad (7)$$

It will be observed that the presence of a receiver has the effect of reducing the power of the non-condensing cylinder when P_m is greater than eP_b as it always should be. The greater the size of the receiver the less the increase of P_m, but this increase of P_m being made gradually and the power taken from the non-condensing cylinder being restored to the condensing cylinder by reason of the increased pressure before cut off occurs it would not seem detrimental to economy to make receivers as small as possible.

If we assume that at end of stroke the pressures in non-condensing cylinder and receiver are the same, we have

$$eP_b[V_n + V_r] = P_m\left(\frac{V_n}{2} + V_r\right) \qquad (8)$$

Letting $P_m = heP_b$ and equating the values of r from 7 and 8.

$$e_1^2 \left\{ \frac{R^2}{4}\left(\frac{h-2}{1-h}\right)^2 + 1 \right\} - e_1 \left\{ 1 + 2R + \frac{R}{2}\left(\frac{h-2}{1-h}\right) \right\} =$$

$$-\tfrac{1}{4}\left(\frac{h-2}{1-h}\right)^2 - \tfrac{1}{4} - \tfrac{1}{2}\left(\frac{h-2}{1-h}\right) \qquad (9)$$

$$\text{Let } A = \tfrac{1}{2}\left(\frac{h-2}{1-h}\right) \quad \text{Therefore } h = \frac{2A+2}{1+2A}$$

$$e_1^2[R^2A^2+1] - e_1[1+2R+RA] = -A^2 - A - \tfrac{1}{4}$$

$$e_1^2 - e_1 \frac{[1+2R+RA]}{R^2A^2+1} = -\frac{A_2 + A + \frac{1}{4}}{R_2A_2+1}$$

$$e_1 = \tfrac{1}{2}\frac{[1+2R+RA]}{R^2A^2+1} + \sqrt{\frac{[1+2R+RA]^2}{4(R^2A^2+1)^2} - \frac{A^2+A+\frac{1}{4}}{R^2A^2+1}} \qquad (10)$$

or

$$A = \frac{2\sqrt{e_1 - e_1^2} - 1}{1 - e_1R} \qquad (11)$$

Since in this equation e_1R must always be greater than unity the denominator must always be a minus quantity.

$$\text{Let } e_1 = \cdot45 \quad A = \frac{2\sqrt{\cdot45 - \cdot2025} - 1}{1 - 1\cdot125} = \frac{+\cdot994 - 1}{-\cdot125} = \cdot048$$

Let $R = 2\frac{1}{2}$

$$h = \frac{\cdot096 + 2}{1 + \cdot096} = 1\cdot91$$

$$r = \frac{\cdot497 - \cdot500}{\cdot125} = \cdot024$$

Again, let $e_1 = \cdot50$, the latest point at which we can cut off.

We have $r = 0$, $A = 0$ and $h = 2$.

We see that the conditions, no drop and great economy of steam, are directly opposed by the demand for equality of power in the two cylinders.

The disadvantage of these high back pressures at mid-stroke in the non-condensing cylinder arises from the diminution of its power.

The only result of using a very large receiver when cutting off steam earlier than the point $\frac{1}{R}$ is to prevent the pressure in the receiver from rising much higher than the terminal pressure of the non-condensing cylinder.

A high back pressure at mid stroke of the non-condensing cylinder

also means a high initial pressure of the condensing cylinder, and consequently increased power in the condensing cylinder.

That is, a large receiver operates to prevent disproportion in the power of two cylinders when proportioned according to the criterion given in the first part of this paper, requiring also that the point $c_1 = \frac{1}{R}$ very nearly, but will be found not to be so economical of steam as a very small receiver or none at all.

The clearances necessarily are regarded as receiver space.

It is very difficult to deduce the mean effective pressure upon the piston head of the condensing cylinder anterior to the cut-off.

If, however, we are satisfied with an approximation as a guide, we can assume $V_r = 0$ and no clearances, and write the following equation for the purpose of equalizing the power of the two cylinders for equal strokes:

$$P_r = \frac{c\,P_b}{c_1 R}$$

$$V_n \left\{ c\,P_b \left(1 + \text{nat. log. } \frac{1}{c}\right) - 2\,P_r \text{ nat. log. } 2 \right\} =$$

$$V_c \left\{ \frac{3}{2}\,P_r\,c_1 + c_1\,P_r \text{ nat. log. } \frac{1}{c_1} \right\}$$

$$\text{Nat. log. } \frac{c_1}{c} = \frac{c_1\,R + 2{\cdot}772}{(2\,c_1\,R)}$$

$$\text{Com. log. } \frac{c_1}{c} = \frac{c_1\,R + 2{\cdot}772}{4{\cdot}6\,c_1\,R}$$

In which we have the limitations c_1 must not be greater than $\frac{1}{2}$ and $c_1\,R$ must not be less than unity.

To sum up the discussion:

With cranks at right angles, we cannot cut off later than one-half stroke in the condensing cylinder without a double admission to it, and consequent loss.

We cannot cut off earlier than $\frac{1}{R}$ without pressing the steam from the receiver back into the non-condensing cylinder, because the steam will rise to a higher pressure in the receiver than the terminal pressure in the con-condensing cylinder. If this is done only to a small extent it may not prove a serious evil.

If we use a receiver of any considerable size we must submit to a drop from the terminal pressure of the non-condensing cylinder to the pressure in the receiver, with the consequent loss, or make $e_1 = \frac{1}{R}$ very nearly.

If we do not use any receiver, or a very small one, we can effect a greater economy of steam, but the power of the two cylinders cannot be equalized without pushing the ultimate expansion beyond all reasonable limits, diminishing the concentration of power so essential to all steam engines, unless we make the point of cut-off of the condensing cylinder later than $\frac{1}{2}$ stroke, and thus submit to a double admission.

In conclusion the writer would like to say that he does not believe that a final agreement will be reached from one discussion or many discussions, or that we can refer our reasoning back to nature and prove its correctness or its superficiality, until a more complete and rational set of experiments are made on the compound engine than now exist.

A famous English lawyer is reported to have said that he could "drive a coach and four through any act of Parliament."

It would require but very little effort to do the same to any set of experiments now extant upon the compound engine.

Forms of Comets' Tails.—Th. Schwedoff has shown that comets' tails may be represented by waves, produced by the passage of the nucleus through a resisting medium. His theory has the advantage of dispensing with the assumption of any doubtful agencies, and of predicting the form and position of the tail in any comet of which the elements are known. Faye has endeavored to demonstrate that the hypothesis of an interplanetary resisting medium would require a mass, within the limits of our system, a hundred thousand times as great as that of the sun, even if the density of the medium were only $\frac{1}{2,000}$ as great as that of our atmosphere. He supposed, however, that the æthereal density does not vary between the surface of the sun and the orbit of Neptune. If we admit, with Encke, that the density of the cosmic medium decreases in inverse ratio to the square of the distance, we readily find, for the total mass of the medium, a value which is only $\frac{1}{13,000,000}$ as great as Faye assumes.—*Comptes Rendus*, May 7, 1883. C.

REPLY TO MR. THEO. D. RAND'S PAPER,

ENTITLED "NOTES ON THE GEOLOGY OF CHESTER VALLEY AND VICINITY, IN THE PROCEEDINGS ACADEMY NATURAL SCIENCES, NOVEMBER, 1883.

[Prefatory Note.—In the *American Naturalist* of May, 1883, the writer reviewed a publication of the Mineralogical and Geological Section, marked "No. 2, 1880-1881." The only articles in this publication of any length or importance were by the Director, Mr. T. D. Rand.

Both of these were mainly devoted to criticizing the work of Mr. Chas. E. Hall, formerly an Assistant on the Second Geological Survey of Pennsylvania. While many of the criticisms may have been well founded, it seemed to the present writer that the tone of the criticism was unjust, and the implied charge of incompetency, unfounded. As Mr. Hall was absent from the city, and unable, therefore to undertake his own defence, the writer replied for his former colleague, from whose views, however, he differed widely, in the *American Naturalist* of May, 1883. Mr. Rand rejoined in September of the same year, raising, among other questions, that of the accuracy of one of my dates, which was therefore established on the authority of the Secretary of the Board, Mr. Forman, in a short note in the same publication in October.

In the meantime, in the September number of the Franklin Institute Journal, Mr. Rand had criticised, with considerable severity, over his well-known initials, the volume C_4, which had recently appeared. This led to an answer by me in the October number of the Journal.

Mr. Rand then, under the title of "Notes on Chester Valley and Vicinity," read a paper strongly combating views which had been, in various places, expressed by or ascribed to me. I had not expected this, though I was accidentally present at the meeting, and replied orally to the points that I happened to recall. Mr. Rand was kind enough to allow me to see his manuscript, in which I found some expressions which I did not remember to have heard.* My reply to this paper, written with the manuscript before me, was submitted to the Mineralogical and Geological Section for publication with Mr. Rand's paper, and was not published by that committee, but referred to the Publication Committee of the Academy itself. This committee accepted it, provided three passages marked by the committee were omitted. In the following, these passages are italicized. I considered them of trifling importance, but could not acknowledge the justice of the committee's demand, and withdrew the paper.

The second of these three passages concerned the present writer alone, and, as he did not feel too badly about it, he was at a loss to comprehend the vicarious sensibility of the committee.—P. F.]

Mr. Theodore D. Rand presented to the notice of the Mineralogical and Geological Section of the Academy of Natural Sciences, on Octo-

* I was absent for a few minutes during the reading of Mr. Rand's paper for the purpose of getting from the library one of the volumes criticized.

ber 21, 1883, an interesting series of rocks, illustrative of the belts in the vicinity of the region where Chester, Delaware and Montgomery counties join; and has given utterance to some categorical criticisms on the newly issued volume C_4 of the publications of the Second Geological Survey of Pennsylvania.

There are eight of these numbered criticisms, but this does not include quite all, because sometimes two criticisms are included under one number; and the criticisms continue after the numeration has ceased, *as if the mathematical faculty could not keep pace with the multitude of impressions due to a sensitive geological judgment.* It is perhaps fortunate for me that, in replying to those criticisms which concern me, I am able to set aside, at the outset, so large a proportion, relating to matters for which I am in no way responsible, and which I saw for the first time after the volume C_4 was printed.

To speak more specifically, criticisms 2, 3, 4 and 7 are such as have just been alluded to. They are directed at statements made by other persons than myself, and with which I either have no sympathy or concerning which have formed no opinion.

No. 6 is really in the same category as the preceding, because it attacks simply a quotation, for which I gave the authority, regarding a state of things outside of the district I was studying, and which I had never seen.

There remain three numbered and four unnumbered criticisms. In regard to these collectively I cannot repress my surprise at their inaccuracy; and in most cases so great is the inaccuracy that were it not for Mr. Rand's (no doubt unintentional, but careless) misquotation, there would be nothing left to base the criticism upon. For example, Mr. Rand quotes as follows: "C_4 says, pp. 34, 124, 'The quartzite failed altogeter on the southern side of the valley.' 'No Potsdam sandstone has been detected anywhere along the south edge of the limestone area.'"

If the reader will turn to p. 34, he will find the sentence preceding the first just quoted to read thus: "When *Chester county* was reached, all sharply defined boundaries ceased to be possible. The quartzite failed," etc., as above.

If one turns to the bottom of p. 123, he reads the following from Prof. Lesley: "Prof. Frazer draws attention to the fact that the *Lancaster county* limestone plain does not seem to rest upon a floor of Potsdam everywhere, but only in its middle and northern parts. The

uplift which crosses that county east and west just north of the city of Lancaster, exposes the Potsdam sandstone several hundred feet thick in Chikis rock on the Susquehanna above Columbia and also at the west end of the Welsh mountain (Laurel Hill, in Earl township), and the Potsdam sandstone is exposed more or less evidently along the edge of the limestone along the Chester county line as far south as the Gap in the North Valley hill and somewhat further west, but no Potsdam sandstone has been detected anywhere along the southern edge of the limestone area, it seems to be replaced by Roger's primal slates."

It is evident from the above complete quotations that on p. 34 I was speaking of *Chester county exclusively*, and on p. 124 Prof. Lesley was citing my opinion of structure in *Lancaster county exclusively*." Inasmuch as the supposed occurrences of Potsdam near the King of Prussia, and in Cream Valley, mentioned by Mr. Rand, are in Montgomery county, which was out of my field of labor, and was not included in either of the citations, his criticism contains nothing to answer.

The second criticism refers to the words, "sandy gneiss"* and "hard serpentine-like mineral," which are supposed to occur on p. 283. What is said there is, "A decomposed friable white gneissoid rock, together with a hard serpentine-like rock, cross the railroad about Wayne Station." The former is evidently the Eurite, about which Mr. Rand has so much to say.

The second observation is very vague, as its author often permitted himself to be in regions outside of that which was the object of his study, viz., Chester county.

How close or what was the analogy between the hard rock in question and serpentine he cannot now say, nor was it his business to say anything about the locality at all. To conclude from "serpentine-like" that the author meant serpentine, would be to entirely alter the intended sense of the passage. But it is worth while to observe how very inexact this quotation is.

Criticism No. 8 seems the only one fairly justified by the text of C_4, p. 282. The context does seem to imply that the serpentine and schistose matter were together in place. With the dip mentioned and fairly within the county of Chester, I frankly confess I am unable,

* Since retracted in a foot-note.

from memory, to state to what this observation refers, as the field notes were made four years ago. I further confess that having recently examined the quarry near the Spread Eagle, and on the north side of the Lancaster turnpike, I am prepared to state that it is in a dark gneiss, as different from serpentine as it is from the white "Eurite" near Wayne, which, as well as itself, is ascribed to the Potsdam by Mr. Rand. I must bear the blame of an error here for the present.

The first unnumbered criticism of my work refers to an article published by me in the May number of the *American Naturalist,* where I am said to have contended rightly "that the region contains hydromica schist *only.*" I challenge Mr. Rand to produce evidence for this statement. Certainly the rocks which preponderate are schists, containing mica of the Damourite group, and these are the rocks that have been taken for talc schists, but I have nowhere said that they were the *only* rocks exposed in this region, nor have I ever thought so. In answer to the question, "Do they contain chlorite?" I reply, I believe they do.

The second unnumbered criticism is based upon an error, but this time of Mr. Rand himself, which he handsomely acknowledges in a foot-note. In the September number of the FRANKLIN INSTITUTE JOURNAL, p. 228, he says: "The trap (pp. 87 and 218) on the north side of the serpentine, Easttown, is not on the map." To this statement I demurred. In point of fact, it may be observed there plainly. Of this Mr. Rand says, in his new criticism: "I inadvertently located this" [absence of trap] "in Easttown. It is really in Willistown." As to the new charge of omission, I will examine into it at the first convenient opportunity.

Mr. Rand desires to know if in stating that Rogers' altered primal, as colored on his map, included a heterogeneous collection of rocks, I may not have included with it some adjacent rocks, I refer him for answer to the large and complicated area covering parts of Chester and Delaware; the entire southern portion of Lancaster, from Turkey Hill to Maryland, and all that portion of York southeast of the limestone belts. This territory contains within it all the rocks I have named.

If there be any allusion to the serpentine belt of Radnor and Easttown on page 33 of the publication of the Mineral and Geological section, it is so covert that I fail to perceive it; certainly there is no "assertion" to that effect, which was Mr. Rand's original language. Page 34 being a map, naturally contains no assertion of any

kind. But, as I said before, this is mere trifling and waste of time, and was good-humoredly introduced to show how Mr. Rand's own method of criticism would apply to his own work.

That Mr. Rand described his "echelon structure," not as a theory, but as a fact, I am quite willing to believe. I did not go further than to suggest as a possible hypothesis the structure I proposed. *If subjective certainty be the test of accuracy, I grant that Mr. Rand is more likely to be right than mere students of nature.*

Finally, it is indisputable that this firing at long range in the columns of scientific journals and the Proceedings of scientific bodies (in regard to phenomena almost at our doors) is neither profitable nor edifying. I thank Mr. Rand heartily for every error he has exposed, whether mine or another's, and my only wish is that the truth may become apparent at the earliest moment, no matter whose theories may be overthrown.

In the above criticisms, out of thirteen, numbered and unnumbered, but seven apply to my part of C_4. Of these seven, but one is well founded, one is trivial, and the other five are based upon such inaccurate statements, that to four of them, were it not for Mr. Rand's high character and conscientious work I would not reply at all. Under these circumstances Mr. Rand should practice a large charity for the shortcomings of others. I quite believe that his observations were made on foot, and I make no reply to the ungenerous charge that "if all the observations of * * * C_4 had been thus made there would have been fewer blunders to correct," except to say that the above examples are very far from proving this statement. That there are many and serious errors in my part of C_4 is probably true: (how could it be otherwise with notes printed without the supervision of their author a year or two before they were intended for the press); but Mr. Rand has only brought possibly one of them to light.

PERSIFOR FRAZER.

In reply to Dr. Frazer, I would say:

1. C_4 and my paper are published. The accuracy of my quotations may be verified by any one who desires.

2. I submit that the observer going southeastwardly from Lancaster county (C_6 p. 34), the phrases, "When Chester county was reached * * * the quartzite failed altogether on the southern side of *the valley*," and (p. 281) under Tredyffrin. "This is the easternmost of the valley tier.* * * *

* Hence next to Montgomery and within a very short distance of the sandstone outcrops described.

Absence of the quartzite on the southern edge of *the valley*, a problem of the utmost difficulty," naturally import the *whole Chester Valley*, and not a part of it only, and the contention that on p. 124, Prof. Lesley was speaking of Lancaster county exclusively, would have fallen had the quotation been continued but a few lines further, as follows: "It is not unreasonable therefore to suppose that the original *southern limit* of deposition of the sandstone was a line drawn from Pomeroy west to Columbia.* * * But this renders it the more extraordinary to find exposures of what seems to be Potsdam sandstone * * * in *southern Chester county*."

If it is admitted that a sandstone does occur on the southern side of the Chester valley, very close to the Chester county line, as described by Prof. Lewis, in 1879,* it would seem that the county line should not have been an impassable barrier to its examination, as prominence is given to the supposed absence of sandstone in that position. In other parts of the work there are observations in Montgomery and Delaware counties.

3. Is it seriously contended that unaltered diorite is a "serpentine like" rock?

4. As to chlorite in the hydromica schists, I quote from Dr. Frazer's criticism of C_4 in the *American Naturalist*, October, 1883. "These rocks contained no talc whatever, the mineral that was taken for talc being a hydrous mica of the damourite group; * * * yet the old name, talc mica region is retained as if it actually defined something, * * * the magnesia which these schists are supposed to contain (contrary to the results of repeated analyses by Dr. T. S. Hunt, Dr. Genth, Mr. McCreath, the writer, and many others), is made the basis of an hypothetical speculation."

From this I inferred, it seems wrongly, that Dr. Frazer contended that these schists were exclusively hydromica schists. I regret that I misunderstood him, but I cannot yet see how schists, which contain no magnesia, can contain chlorite any more than they can contain talc. Can he refer to an analysis of specimens from a locality not close to the line of serpentine outcrops?

5. Dr. Frazer says: "If there be any allusion to the Serpentine belt of Radnor and Easttown on page 33,† it is so covert that I fail to perceive it. * * * Page 34, being a map, naturally contains no assertion of any kind." I quote from page 33: "My view of a section along a line from Bryn Mawr northwest to a point in the north line of Radnor township, * * * that is west of Mr. Hall's line H, * * * is given herewith, * * * 1. Syenite. Northward. 2. *Serpentine*. * * * I submit herewith a map showing most of the outcrops mentioned." On the next page is the map, showing among other things the outcrops of the Radnor and Easttown Serpentine belt on the northerly side of the great Syenite anticlinal. A map may not be an "assertion," but if one publishes a geological map, and upon it indicates clearly the outcrop of a certain rock, it is a fair inference that he meant that such a rock was in the locality marked.

6. Dr. Frazer insists on the accuracy of his date for the publication of C_6,

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* Proc. Min. and Geol. Soc. Acad. N. S., No. 1, p. 93.

† Rand, Proc. Min. and G. Sec., 1880, 1881, p. 33.

viz., "late in 1882."* I stated† that that volume was in the library of the Academy, and in my possession, in 1881; that my criticism of it was read in December, 1881, and published in April, 1882; which statements, if the book was not published until late in 1882, as Dr. Frazer again asserts, cannot be true. Until now I supposed his remarks in the October *Naturalist* were intended to explain how he fell into the error, and not to affirm it; but his present statement is so clear that I feel compelled to publish the following to relieve myself of the odium of such a charge:

HARRISBURG, PA., Nov. 30, 1881.

THEO. D. RAND, Esq., 17 South Third street.

DEAR SIR:—At the request of Mr. Murray Graydon, * * * I send you by mail to-day 1 copy of Report C_6. * * * * * *

Very truly, FRED'K W. FORMAN.

[Copy.]

Second Geological Survey of Pennsylvania.

J. PETER LESLEY, State Geologist,
1008 Clinton street, Philadelphia.

MARCH 13, 1884.

Mr. THEO. D. RAND.

DEAR SIR:—C_6 was published, I think, in September, 1881; but, as the publication office at Harrisburg was under the direction of the Secretary of the Board, and as his clerk is no longer in the service of the Survey, I am unable to give a more accurate date; indeed, it would be impossible for any one to fix a date.

Yours truly, J. P. LESLEY, per H.

Equally with Dr. Frazer do I deprecate the "firing at long range." For this very reason, I, pursuant to a published promise, produced the rocks themselves at the meeting of the Mineralogical and Geological Section of the Academy, hoping that the points of difference might be there amicably discussed and the truth elicited. It is the right of every observer to set forth his observations, even though they may differ from the views of those engaged in the survey of the State.

THEO. D. RAND.

Regarding which Dr. Frazer rejoins:

"With one printing press and one official channel open to him, which are closed to me, it is clear that Mr. Rand can print more words in a given time. The above paragraphed reply seems to me to be characterized by 'undistributed middle,' not to say pettifogging. For instance, No. 2 is an obstinate attempt to put in the mouth of another what that other never said, and has denied having ever meant. In the face of such a fact the effort to fasten upon my words such repudiated meanings is quite unfair. Such phrases as 'naturally import' (No. 2), the comment on Prof. Les-

* Frazer, Am. Nat., May, 1883, p. 523.
† Am. Nat., September, 1883, p. 966.

ley's language (No. 2),* 'fair inference' (No. 5), and the quibble about the chlorite in the hydromica schists, are purely gratuitous constructions which it pleases Mr. Rand to put on language which will not sustain them.

"Nos. 3 and 5 appear to me to be the veriest trifling with words.

"No. 4 is an entire misstatement of my clearly expressed views. Though the 'talc schist' contain no talc, and therefore no magnesia, it does not follow that in the series there are no layers of magnesian rocks which are *not* 'talc-like.'

"In C_3 pp. 268† +, several analyses of such rocks remote from the serpentine outcrops will be found.

"(6) I *did* insist that C_6 was published October 24, 1882, for the reason that on writing to the clerk of the Board of Commissioners, Mr. F. W. Forman, who was the official charged with receiving, issuing, and recording the date of issue of reports, I received and have still a letter dated September 8, 1883, in which the dates of issue of all the reports up to that time are given, and that of the issue of C_6 is October 24, 1882. If Mr. Forman was mistaken I am not to blame, because having been in Europe during the entire period between Mr. Forman's date and Mr. Rand's I took every precaution to ascertain with accuracy what I stated. The State Printer, however, in answer to a letter from me, fixes the date of the delivery of 1,400 copies of C_6 to Mr. Forman as October 24, 1881."

PERSIFOR FRAZER.

Commenting upon the preceding, Mr. Rand adds:

"Of the analyses C_3, p. 268, two are of rock from *York* county. The third is in Lancaster, as follows; the ?? are in the original:

"No. 977, Variegated Chlorite Schist with Chlorite (?) half a mile northeast of Pine Grove.

Silica ($Si\,O_2$)	37·03
Titanic Oxide ($Ti\,O_2$)	4·05
Phosphoric Oxide ($P_2\,O_5$)	0·51
Alumina ($Al_2\,O_3$)	24·13
Lime ($Ca\,O$)	·21
Magnesia ($Mg\,O$)	1·44
Ferrous Oxide (?) ($Fe\,O$)	19·83
Potash, trace soda	8·93
Ignition	3·54

"This needs no comment. The Map C_3 shows the locality in the line of strike of the Texas Serpentine, and but about two miles distant."‡

THEO. D. RAND.

* The added words only prove more conclusively than ever that the quotation could not justify Mr. Rand's supposition that C_4 denied the existence of quartzite on any part of the southern side of the Chester valley, and that Lancaster and Chester were alone under consideration. Lancaster, up to the point where my citation stopped, and by a natural transition of thought in the portion continued by Mr. Rand, Chester

† 268 + means p. 268 and succeeding pages. Mr. Rand asked for an analysis of specimens (of hydro-mica schists) not near a serpentine outcrop. I referred to p. 268, where there are three analyses of the associated chloritic layers; + (*i. e.*, p. 270) Peach Bottom slate, (and p. 271,) mica schist. His remark about 977, (a specimen from the west slope of the South Mountain in Cumberland county,) which follows this, I cannot understand. His assertion as to the locality is some fifty-six miles in error, the horizon is probably the same as that of the Chester schists and magnesia is present.

‡ Dr. Frazer's note leads me to think there may be two *Pine Groves*. If fifty-six miles from Pine Grove on the Octorara it is equally with York county out of the region discussed.

Distribution of the Heat which is Developed by Forging.—On the 8th of June 1874, Tresca presented to the French Academy some considerations respecting the distribution of heat in forging a bar of platinum, and stated the principal reasons which rendered that metal especially suitable for the purpose. He subsequently experimented, in a similar way, with other metals, and finally adopted Senarmont's method for the study of conductibility. A steel or copper bar was carefully polished on its lateral faces, and the polished portion covered with a thin coat of wax. The bar thus prepared was placed under a ram, of known weight P, which was raised to a height H, where it was automatically released so as to expend upon the bar the whole quantity of work $T = PH$, between the two equal faces of the ram and the anvil. A single shock sufficed to melt the wax upon a certain zone and thus to limit, with great sharpness, the part of the lateral faces which had been raised during the shock to the temperature of melting wax. Generally the zone of fusion imitates the area comprised between the two branches of an equilateral hyperbola, but the fall can be so graduated as to restrict this zone, which then takes other forms, somewhat different, but always symmetrical. If A is the area of this zone, b the breadth of the bar, d the density of the metal, c its capacity for heat, and $t - t_0$ the excess of the melting temperature of wax over the surrounding temperature, it is evident that, if we consider A as the base of a horizontal prism which is raised to the temperature t, the calorific effect may be expressed by

$$Ab \times d \times C(t - t_0)$$

and on multiplying this quantity of heat by 425 we find, for the value of its equivalent in work,

$$T^1 = 425\, AbdC(t - t_0).$$

On comparing T^1 to T we may consider the experiment as a mechanical operation, having a minimum of

$$\frac{T^1}{T} = \frac{425}{PH} AbdC(t - t_0).$$

After giving diagrams and tables to illustrate the geometrical disposition of the areas of fusion, Tresca feels justified in concluding that the development of heat depends upon the form of the faces and the intensity of the shock; that the points of greatest heat correspond to the points of greatest flow of the metal and that this flow is really the

mechanical phenomenon which gives rise to the calorific phenomenon; that for actions sufficiently energetic and for bars of sufficient dimensions, about $\frac{8}{10}$ of the labor expended on the blow may be found again in the heat; that the figures formed in the melted wax, for shocks of less intensity, furnish a kind of diagram of the distribution of the heat and of the deformation in the interior of the bar, but that the calculation of the coefficient of efficiency does not yield satisfactory results in the case of moderate blows.—*Comptes Rendus*, July 23, 1883.

Strength of Portland Cement.—The Portland cement, as it comes from the factory, is composed of an almost impalpable powder, mixed with coarser grains which have but little adhesive quality. Mann's experiments have shown that in a trial of seven days the portions which pass through a No. 176 sieve (31,000 meshes per square inch) exhibit five times the adhesive strength of those which pass through a No. 103 sieve (10,600 meshes per square inch). The necessity of fine grinding is therefore obvious. In ordinary cement 45·6 per cent. is stopped by the No. 176 sieve, which is the finest that is made. The force of cohesion is much greater than that of adhesion, varying from threefold to tenfold. The adhesive force upon different substances, such as stone, brick, slate, marble, glass, etc., varies greatly. The degree of surface polish has less effect than one would think. According to these experiments, the best test of Portland cement is its adhesive power. The No. 176 sieve ought not to stop more than 45 per cent. of the cement; the part which traverses the sieve should have an adhesive force of 95 pounds, and the unsifted cement of 75 pounds per square inch.—*Chron. Industr.*, Sept. 30, 1883. C.

Tripolith.—A substance has been manufactured in Heidleberg, for two years, which is called *tripolith*, and which is prepared as follows: three parts of an argillaceous gypsum are mixed with one part of silicious clay, and nine parts of this mixture are added to one part of coke. The entire mass is placed in a caldron, without water, and is heated, with continual stirring, until it reaches the temperature of 120° (248°F.), in order that the water of crystallization may be expelled from the gypsum. The whole is then heated to 260° (500°F.), and subsequently pulverized and sifted. The tripolith is harder, tougher and lighter than gypsum, and is better adapted to the manufacture of stuccos and the decoration of columns, etc.—*Gaceta Industrial*, Sept. 25, 1883. C.

Manufacture of Soda from Sea Salt—The municipality of Issoudun, having resolved to erect a monument to Nicholas Leblanc, the pioneer in the artificial soda industry, M. Dumas gave an eloquent address to the French Academy upon the importance and vicissitudes of that branch of manufacture. A hundred years ago the French Government consulted the Academy as to the best means of replacing the soda supply, for which they had been dependent upon Spain, and a prize of 12,000 francs was offered to the inventor of a successful process for extracting the alkali from sea salt. When Leblanc had fulfilled the conditions of the prize the Academy had ceased to exist; the inventor was obliged to renounce his rights, to close his factory and to live in the extreme of penury, until finally he committed suicide. Many persons would be surprised at the information that the two greatest economical novelties of the century are the steam engine and artificial soda, the two most fertile inventors, Watt and Leblanc. While the engines created by the former act with a great noise in all our factories, carry the trains of travelers and merchandize over the iron roads with which the continents are furrowed, or guide ships of commerce and war over the waves of the sea, the soda products penetrate into all our workshops and dwellings, as indispensable elements or auxiliary agents of labor, and as direct or indirect objects of consumption. If we were asked which of the two inventors, Watt or Leblanc, has most greatly increased the welfare of our race, we might hesitate for an answer. All the ameliorations in the mechanic arts spring, it is true, from the use of the steam engine; but all of the benefits which pertain to the chemical industries have found their point of departure in the extraction of soda from sea salt. The first result of the soda factories placed at the disposal of the soap makers, the glass manufacturers, the bleachers and the paper makers the alkali of which they have need, and also offered to all industries sulphuric and chlorhydric acid, in unlimited quantities and at prices fabulously reduced. The second result was the introduction of chloride of lime for the rapid bleaching of vegetable tissues, in place of the slow action of solar light and damp air upon pieces of linen spread upon the grass. These four agents—a powerful alkali, two energetic acids, a bleaching powder which nothing has supplanted—gave an unprecedented range to chemical industries, and raised the question whether it was wise to leave the fabrics dependent upon the sulphur of Sicily, which might, at any moment, be enormously advanced in price; and iron pyrites,

which had previously been almost worthless, was largely employed in the manufacture of sulphuric acid. The growth and competition of large soda factories reduced the price until it became necessary to look for new sources of profit, which were found, for awhile, in the manufacture and sale of chloride of lime. The leaching of the crude soda to extract the carbonate left residues, which contained all the sulphur of the sulphuric acid united to the lime. This refuse incommoded the whole neighborhood, infecting the water courses and the shores of the sea itself. These annoyances were removed by the invention of a process for regenerating the soda which was left from the leachings. The manufacture of chlorine and chloride of lime consumed peroxide of manganese, and produced chloride of manganese in great quantities. The peroxide is a natural product of limited supply; to increase its consumption is to raise its price. The chloride destroys vegetation and infects the streams; a considerable daily production of it creates a thousand difficulties. They have been obviated by a process for regenerating the peroxide and thus getting rid of the chloride. Meanwhile, the competition continuing, and the price of soda steadily falling in proportion as the cost of manufacture diminished, help was sought, not in new economies, but in the treatment of ores capable of furnishing remunerative merchantable products. Hence the iron pyrites was replaced by copper pyrites which were accompanied by precious metals, and the profit was sought in the silver or gold which could be extracted from their cinders. This strife is now to be renewed with a rival process founded upon the decomposition of salt by ammonia in presence of an excess of carbonic acid. Whatever may be the result of the contest, it is fortunate that modern chemistry has had the various practical schools of industry which have resulted from Leblanc's process, and which have exercised an incalculable influence upon all civilized countries.—*Les Mondes*, Aug. 11, 1883. C.

Dangers in the Use of Earthenware.—E. Peyrusson, having been called upon to examine some pottery which was suspected of having produced lead-poisoning, found that, in spite of the ministerial circulars, the glazing often contains lead enough to make it dangerous for use. M. Constantin has invented a process which is entirely harmless as well as economical—varnishing with boro-silicate of lime. The glazing of fine French and English china has been much improved by the addition of boric acid and borate of lime, which allows a great

diminution in the quantity of ceruse employed; but even their habitual use may occasion injury by the accumulation of small quantities of lead in the system. There are always cracks in the glazing even of the finest china after it has been used for some time. These cracks may retain, in spite of the most careful washing, germs of fermentation, as is shown by the fact that milk or broth will ferment more readily in a vessel which has once been soured than in one which is new. The analogy between fermentation and contagious diseases gives room to fear that earthen vessels which have been used by the sick may carry contagion to others.—*Les Mondes*, Aug. 25, 1883. C.

New Mining Powder.—According to the *Annales Industrielles*, M. Michalowski, an engineer at Monteeau-les-Mines, has just invented a new explosive. It is a powder of a density little more than half as great as that of ordinary powder, with irregular grains of a slate-gray color. It does not explode by the action of fire, and detonates only under a blow, like dynamite.—*Les Mondes*, Aug. 25, 1883. C.

Book Notices

TRAITÉ PRATIQUE D'ÉLECTRICITÉ COMPRENANT LES APPLICATIONS AUX SCIENCES ET L'INDUSTRIE, ETC. Par C. M. Gariel. Tome Premiere. Avec 253 figures dans les texte. Paris: Octave Doin, Editeur. 1884.

The intention of the author is at once to avoid the classic routine of the ordinary text-book on electricity, and to present the more important developments of electrical science in such form as may be particularly instructive to the general or non-technical reader. Instruction, as the main object, is followed with honest plodding purpose, to the exclusion of much that might scientifically amuse, and we may say, as we pick this book out of the present frothing flood of light literature on electricity, that it is quite above the average popular work in tone and in execution.

While freshness and point is given to the treatment by keeping the applications steadily in view, the author does not hesitate to explain many essential theoretical matters omitted from works of a more technical pretension. Asserting that it is not necessary in a work of applied physics that the facts should disappear "derrière les equations," the

author for the most part avoids mathematical formulæ. And yet the few formulæ employed are happily chosen, and also clearly show that there is a limit to the popular treatment of even applied science which, for the sake of science and of the applications, it is well to recognize.

We are particularly pleased to find in a popular work chapters on magnetic and electrical measurement so neatly done, and we note throughout the author's clear apprehension of the essentials of electrical science. M. B. S.

DYNAMIC ELECTRICITY, including, I, Some Points in Electric Lighting, by Dr. John Hopkinson, F. R. S.; II, On the Measurement of Electricity for Commercial Purposes, by James N. Schoolbred, M. Inst. C. E.; III, Electric Light Arithmetic, by R. E. Day, M. A. Science Series, No. 71. New York: D. Van Nostrand.

This little volume will be read with interest by those engaged in the practical manipulation of dynamic electricity. The joint issue of three essays like these does not detract from either, and may prove an advantage. The first treats more particularly of the theory of the dynamo circuit, the second of the practical measurement of electrical effect, and the third contains the numerical solution of some problems arising in the daily practice of electric lighting. M. B. S.

THE INTERNATIONAL ELECTRICAL EXHIBITION.

[To open, Tuesday, September 2d, 1884; to close, Saturday, October 11th, 1884.]

In the JOURNAL for September, 1883, there appeared a general announcement of the intention of the Franklin Institute of the State Pennsylvania for the Promotion of the Mechanic Arts, to hold an International Electrical Exhibition in the autumn of the year 1884, and giving the text of the Act of Congress relating thereto, which provided for the admission into the United States, duty free, of all articles intended for the exhibition.

Since this publication was made, the committee on exhibitions has been actively engaged in the work of organizing and perfecting the plans. At the present time much of this preliminary work has been completed, and that remaining to be done is in as advanced a state as time and circumstances have permitted.

Briefly summarized, the steps that have been taken are the following: A suitable site for holding the exhibition has been obtained in

the large vacant lot bounded by Thirty-second and Thirty-third streets, Lancaster avenue and Foster street, which, by the liberal action of the Pennsylvania Railroad Company, has been leased to the Institute for the purposes of the exhibition for a nominal consideration.

The accompanying plate (see frontispiece) is a view of the exhibition building, which is now in process of erection, and which, by the terms of the contract, will be finished by the 15th of June. The building is being erected by Mr. Jacob R. Garber, from the plans of the architects, Messrs. Wilson, Brothers & Co.

The following brief description will give a general idea of its character:

The main building will be rectangular, having a length on Foster street of 283 feet and a breadth of 160 feet, extending from Foster street to Lancaster avenue on Thirty-second street, and part of the distance from Foster street to Lancaster avenue on Thirty-third street. A tower sixty feet high will be situated at each of the four corners of this building. One central arch of 100 feet span and 200 feet in length, of the Gothic style of architecture, will cover the greater portion of the space occupied by this building, while two smaller ones, having a span of thirty feet and running parallel to it on either side, will join the towers. The building will have second story apartments at its ends on Thirty-second and Thirty-third streets respectively, with stairways leading up in the towers from the ground floor. The towers themselves will be three stories high. Two long and narrow hallways will afford communication between these apartments. The remainder of the ground will be enclosed by a large triangular building one story in height and joined to the main hall. The main entrance to the building will be at the corner of Thirty-second street and Lancaster avenue, another at Thirty-third and the avenue, and one at each of the other towers. Five exits are provided for on the plans, but desirable changes may hereafter be made in the number and situation of both entrances and exits before the work is completed.

The meeting of the American Association for the Advancement of Science, which will be held this year in Philadelphia, and the expected presence of many representatives of the British Association, which will meet this year in Montreal, will attract a numerous and influential scientific gathering in Philadelphia during the time of the holding of the exhibition; and in order that so exceptional an opportunity to promote the interests of science shall not be lost, Congress has been

requested to authorize the holding of a National Conference of Electricians, to convene in Philadelphia at this time. Should Congress, in its wisdom, make the proper provisions for holding such a conference, the results promise to be of much value.

The scientific character and importance of the exhibition have been duly appreciated by the United States Goverment, and the following official letter issued by the Department of State, conveying instructions to our diplomatic officials abroad, is at once as complete an endorsement of the project as could be given, and a flattering tribute to the reputation and usefulness of the Franklin Institute.

[COPY.]

DEPARTMENT OF STATE,
Washington, March 1, 1884.

SIR:—I transmit herewith printed copies of a circular issued by the FRANKLIN INSTITUTE of the State of Pennsylvania, respecting an International Electrical Exhibition to be held at Philadelphia, from September 2d to October 11th, 1884.

Although the exhibition will be organized and conducted apart from the immediate control of the United States, the advantages for useful results, which a direction by the FRANKLIN INSTITUTE confers, have been distinctly recognized by Congress. The Joint Resolution of February 26th, 1883, extended the privilege of "free entry" to all articles from abroad which shall be intended and used for the purpose of the exhibition, and precise instructions have in consequence been formulated for the guidance of Customs officers.

It is likewise proper that the offices of our representatives abroad should be engaged in the same interest to the extent of bringing the project officially to the attention of the governments to which they are respectively accredited, and, by all suitable methods, of making known to individuals who are or might be interested, the character, standing and profession of the exhibition above designated.

With the object of obtaining from you the service just indicated this instruction is addressed.

I am, sir, your obedient servant,

(Signed.) FRED'K T. FRELINGHUYSEN.

A comprehensive scheme of classification has been carefully elaborated; a system of rules and regulations to govern the internal management of the exhibition has been adopted; provisions have been made in the interest of intending foreign exhibitors, to relieve them of all trouble in respect to the passage of their exhibits through the Custom

House, and for the proper reception and care-taking of the same on their arrival; and arrangements have been made with a number of the leading transportation companies, to return, free of charge, goods on which freight charges have been paid one way.

The above information, expressed in detail, has been published in the form of a twelve-page pamphlet, which, with a blank form of application for space has been issued in the English, French and German languages, and extensively circulated in the United States and throughout Europe.

There are evidences at this time even, to indicate that the exhibition will be one of unusual interest and value. The active participation of several of the scientific bureaux of the United States Government and of all the leading electrical companies is assured. Numerous inquiries both from official and private sources have been received from abroad, and interesting and valuable contributions from European countries are confidently anticipated.

The circular of information herein referred to, with blank forms of application for space, may be obtained in the English, French or German languages, by addressing a request therefor, to the Secretary of the Franklin Institute. W.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, March* 19, 1884.]

Hall of the Institute, March 19, 1884.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham in the chair. There were present 168 members and 12 visitors. The minutes of the February meeting were read and approved. The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, March 12th, 1884, 19 persons had been elected to membership.

The Secretary reported that, pursuant to instructions, he had caused the proposed amendment to Article III, Section 3, of the By-Laws, offered by Mr. Sartain, at the last stated meeting, to be advertised weekly in two of the daily newspapers. The amendment in question proposes the addition to Article III, Section 3, of the words "*provided*, that no payment less than the full contribution for one year shall

entitle the member to admission to the exhibitions." The amendment, after some debate, was unanimously adopted.

Mr. S. Lloyd Wiegand then read a paper embodying the results of the bursting of the model of the Gaffney steam-boiler at the previous meeting, and commented thereon, illustrating his remarks by the exhibition of a portion of the wreck of the original Gaffney boiler, and by lantern slides exhibiting the setting and connections of the same, and the fragments of the broken cast-iron head, showing the character of the fracture. A summary of Mr. Wiegand's remarks will appear in the JOURNAL. The paper was discussed by Mr. J. W. Nystrom, Mr. Washington Jones, and the author.

Dr. W. F. Duncan, of New York, then explained, by invitation, the system and apparatus of the "National Anti-Sewer Gas Company." The plan of the company, briefly stated, embraces the adoption of the system of plumbing approved by the municipal authorities of New York, and a system of cleansing the pipes and traps with specially devised flexible brushes, and of disinfecting the same. The method and apparatus are adapted also to any kind of plumbing. The company proposes to periodically inspect the plumbing of buildings placed under its charge and to keep the same in safe condition.

The Secretary's report embraced remarks respecting the present state of arrangements for the forthcoming International Electrical Exhibition of the Institute (a summary of which appears elsewhere in the JOURNAL); an account of some ingenious improvements in the methods of working the metal iridium, devised by Mr. John Holland, of Cincinnati; a criticism of some highly extravagant publications respecting the cheap production of aluminium; and a description of a number of mechanical and other novelties presented for exhibition. Of these the more important were: A duplex steam-hammer invented by Ed. B. Meatyard, of Lake Geneva, Wis.; a cloth-measuring machine, the invention of Fred'k Sanderson, of Friend, Neb., consisting of a pair of rubber-tired wheels attached to the edge of a table, and to the axle of which is connected a train of clock work carrying an index, which exhibits in yards or any desired measure, the length of cloth passed under the wheels, the rubber tires preventing slipping. There were also shown for the manufacturers, Messrs. Courteney & Trull, of New York, specimens of "gelatinized fibre," adapted for various uses; and the asbestos boiler and pipe covering of the Chalmers-Spence Company.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXVII. MAY, 1884. No. 5.

THE MOST ECONOMICAL POINT OF CUT-OFF.

By De Volson Wood.

In complying with Professor Marks' request in the last February number of this Journal, I hope to remove the grounds for the imputation of any unfairness which he has been pleased to impute to me. In his communication of December last, equation (1) is

$$y = \frac{\text{Mean effective pressure} \times V}{\text{Cost steam} + \text{constant charges} - \text{value saved by compression}} \quad (1)$$

and equation (6) deduced from (1) is

$$y = \frac{cP_b\left[1+\log.\frac{1}{c} - \frac{k}{c}\right] - B\left[1 - b\left(1 + \log.\frac{b}{k}\right)\right]}{c + \frac{C}{D}\left\{cP_b\left[1+\log.\frac{1}{c} - \frac{k}{c}\right] - \left[B - b\left(1 + \log.\frac{b}{k}\right)\right]\right. - b\frac{B'}{P_b}} \quad (6)$$

The second term of the denominator of equation (1) is *constant charges*, while the second term of the denomination of equation (6) is a function of c, a variable. This apparently changes the character of equation (1) and requires explanation. We find, however, if he explains that point, and if we admit his assumption that his "so called" constant charges are a fraction only of the cost of steam, that they

will disappear in determining the maximum of his expression as he claims; for it is equivalent to a function of the form

$$y = \frac{f(\varphi)}{F(\varphi) + af(\varphi) + c},$$

from which we find for a maximum, the relation,

$$[F(\varphi) + af(\varphi) + c]f'(\varphi) - f(\varphi)[F'(\varphi) + af'(\varphi)] = 0;$$

or

$$F(\varphi). f'(\varphi) + cf'(\varphi) - f(\varphi). F'(\varphi) = 0;$$

from which $af(\varphi)$ has disappeared; and it is apparent from the process that the only law which will cause the second term of the denominator of the fraction to disappear, is to make the ratio between it and the numerator constant. If this, then, were the only law, there would be no other solution. If there be any variation from this law, my conclusion, that the solution is *special*, is correct.

In the last February number, Professor Marks states: "That the constant charges are dependent solely on wages, cost of oil, interest, insurance, taxes and probable deterioration of machinery, and independent of all else."

"The person designing an engine knows what horse-power is expected of it."

On page 82, he says: "How is John Doe to get 150 horse-powers for the least sum of money?" "There is no answer save this: *by using the least possible steam per horse-power per hour.*"

On page 84: "I have assumed John Doe to be a manufacturer, who wishes to do that thing which at the end of one year or ten years is most profitable, and not a person cramped for capital."

The problem before us, then, is the *designer's* problem, and not the *owner's* problem.* John Doe having confidence in the Professor, secures his services in selecting the engine which will be the most economical for delivering 150 horse-powers for ten years. From the known initial pressure (say 90 pounds), the back pressure (say 5 pounds), and the clearance (which he assumes to be small), he finds by means of equation (8)

$$e = \frac{B}{P_b} = \frac{5}{90} = \frac{1}{18},$$

* The *designer's* problem consists in making an engine which will deliver a given number of horse-powers most economically; the *owner's* problem consists in delivering the greatest number of horse-powers from a given plant with the most profit to the owner. When the designer has properly solved his problem, it is merged into that of the owner's.

for the approximate value of the cut-off; and for a more accurate value

$$e = \frac{B\left[1 - b\left(1 + \log. \frac{b}{k}\right)\right]}{P_b} + k - \frac{B}{b P_b} \log. \frac{1}{e}, \qquad (7)$$

which for want of data we cannot reduce numerically, and hence will assume it as $\frac{1}{17}$, or even $\frac{1}{16}$. These men go into the market, and with the given data, the Professor selects the engine that will produce the 150 horse-powers "*by using the least possible steam per horse-power per hour;*" excepting that, for commercial reasons, he quietly uses a cut-off of $\frac{1}{10}$* as the basis of selection.

Doe learns from Smith, the proprietor, that the price is $4,000. Doe questions the wisdom of putting so much money into an engine for his business—at any rate, he intends to see if he cannot do better. Smith, desirous of securing a customer, after learning the capacity of the engine desired, offers one for $3,000, which he guarantees will deliver the required power. Mr. Doe then enters into a conversation with these men, which we may imagine runs as follows:

Doe. Do you think, Professor, that the smaller engine will do my work?

Professor. I have no doubt of it; but it will cost you more for steam, every day you use it, than the larger one; and I suppose you want to get your steam for the least money; and I have shown in my publications that the cheapest engine in the long run is one "*that will use the least possible steam per horse-power per hour,*" and the larger engine will do it, and the smaller one will not.

Doe. Steam! I have my boilers set, and they will furnish the steam; it is an engine I am now after.

Professor. Yes, my good sir, but do you not understand that to make steam requires fuel, and fuel costs money; and an engine that uses more steam than is necessary, wastes money; and although this appears evident, some writers "have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work." (Feb., 1884, p. 83.)

Doe. My good friend, you may yet regret criticising those writers in this manner; for sometimes it is *economy* to *waste.* For instance, I could have saved $1,000 in building and stocking my shop had I been six months longer about it; but the interest alone would amount to

* JOURNAL FRANKLIN INSTITUTE, Dec., 1883, and Jan., 1884, p. 41.

more than that, and I expect to make twice that amount in that time. It is barely possible that those writers saw that by *losing* in the cost of steam they could *gain more* at some other point in this problem. But never mind that now, for we must select our engine. Please tell me how the smaller engine can do the work.

Professor. By cutting off later in the stroke. By following the piston with the full pressure of the steam further in the stroke, more power will be secured; but by so doing you will reject more heat in the steam at the exhaust, thus requiring a larger amount of steam, and as we have said, more fuel to do the same work; and I suppose you want to get your 150 horse-powers *"by using the least possible steam per horse-power per hour;"* and this will govern the point of cut-off, and consequently the proper size of the engine to be selected.

Doe. But this $1,000 difference in the first cost is too great for delivering the same power. Mr. Smith, I think your price of the larger engine is too high. Our Professor says: "The cost of an engine is not proportional to the size of the cylinder, but rather to the amount of labor put upon the engine as a whole. (February 1884, p. 84.)

Smith. The Professor is dealing in "general assertions;"* he ought to give "some law, equation, or example." He does not even intimate whether the work put upon an engine as a whole, in practice, bears any relation to the volume of the cylinder. Should I charge you $5,000 for the larger engine, it might not conflict with his statement. The fact is he denies the existence of one element of cost, but in the same sentence admits another element, which opposes his own denial. My experience in the business, and observation of general practice, enables me to say, confidently, that the cost of well-made engines varies with † the volume of the cylinder; that is, an engine with a large cylinder costs more than with a small one. I am able to refer you to some tabulated results on this point by Professor Trowbridge, in the Transactions of the American Society of Mechanical Engineers for 1882, page 231, and of remarks thereon by Professor Thurston, ibid, 1882, Vol. III, p. 289, showing that for engines above 50 horse-power, the cost is approximately as the volumes of the cylinders. The fact is, Professor Marks advocates a short cut-off, and requires a correspondingly large cylinder. You could probably get 200 horse-

* February, 1882, p. 81.

† In the January number I used *with* in the sense of a functional relation, without deciding whether the relation was direct or inverse. D. W.

powers out of the one he has selected, other things being properly proportioned.

Professor. All the dealers charge in that way, and I suppose we must submit to it.

Doc. The question of the cut-off grows in interest. I see our Professor says: "The point of cut-off has, practically, nothing to do with the constant charges, save so far as it determines the volume of the cylinder required."

Smith. I do not presume to understand all that is written about the cut-off; but there is something amusing in this statement of the Professor. As before, he denies one proposition, and then, in my opinion, admits another element which opposes his denial; for in my opinion, the size of the cylinder, involving as it does the cost of the engine, does affect the economical point of cut-off by making the constant charges, so called, different from what they otherwise would be; for the truth of which I appeal to you in the case of the two engines now before you. The consideration of the theoretical effect of constant charges, I leave to the Professor. There is another peculiar expression, "the volume of the cylinder is determined by the constant charges." Does the Professor come here with the constant charges known, and select a cylinder such that the interest, repairs, etc., thereon will produce these charges?

Professor. I should have said that the constant charges are dependent upon the volume of the cylinder.

Doc. Exactly. You have now touched a practical point; for I desire to make those constant charges, as you call them, as small as I can, for I will be obliged to pay for them in some way.

Professor. But remember that the 150 horse-powers will cost you more for fuel with the smaller engine.

Doc. How much more? I am willing to *lose* on the cost of steam, if I can save more on these constant charges. This $1,000 in first cost ought to have some influence on the ultimate economy.

Professor. It would seem so at first sight, but I have considered a case in my discussion of this subject. I observed that by saving $1,000 in first cost of the engine, you could afford to expend more money in producing steam; but to raise more steam, economically, would require larger boilers, and so there would be nothing saved. (Feb. 1884, p. 84.)

Doe. Now you have introduced another element into the problem. Does the capacity of the boilers affect the point of cut-off?

Professor. Not according to my theory, for they enter, if at all, as constant charges (the conclusion, however, being said hesitatingly after the remark above by Smith).

Doe. But it appears to me that you reached your result very abruptly. You speak definitely, of saving $1,000 and $3,000, and then quickly conclude that "we can safely set off against any possible saving effected by diminishing the size of the steam cylinder, the greater cost of increase, logically required, in the size of the boilers." (P. 84.) I see no figures to substantiate this conclusion; did you work it out thoroughly?

Professor. I did not compute it very accurately, but you will readily see that an engine requiring more steam may require larger boilers.

Doe. Not necessarily so, for it might be *economy* to *lose* on the fuel and save the cost of enlargement. Suppose that the interest, repairs, etc.—"constant charges"—are 16 per cent. on this purchase, I would save $160 per year if the smaller engine will answer. If my boilers are somewhat under size, perhaps $50 per year extra in fuel will supply the steam, in which case there will be a decided saving. Please examine these specifications of my boilers and inform me if they have sufficient capacity for the smaller engine.

Professor (after figuring). They will answer.

Doe. The boilers being out of the question, does it not follow, from your own reasoning, that it may, and probably will, be more economical for me to purchase the smaller engine.

Professor. Well, it appears so; but I still assure you that *the larger engine will give you the* 150 *horse-powers with less cost for fuel than the smaller one.*

Doe. My good friend, why do you continually bring to the front that proposition. I take a broader view of this transaction. It is not steam I want to save, but money. "I am a manufacturer, who wishes to do that thing which at the end of a year, or ten years, is most profitable" (p. 84); and your theories are not worth the paper they are printed on, if they tend to mislead me.

Professor. But I have shown in my writings that "your only opportunity *of saving money lies in saving steam per horse-power per hour.*" Here it is in the last February number of the Journal of the Franklin Institute, page 83.

Doe (reading). I see you make the assertion, but I do not see the argument. You have asserted that the saving in cost of engine must be expended in increased cost of boilers, or fuel, or both, but this needs confirmation; but, fortunately, in my case, the boilers are out of the question. Now are you not forced to admit that it will be economy for me to purchase the smaller engine, provided I save annually \$160 in interest, repairs, etc., and expend \$100 more for fuel, than I would if using the larger engine.

Professor. As you put it I must admit it.

Doe. But the smaller engine has a longer cut-off than your theory gives; must you not admit that these charges, of interest, repairs, etc. influence the most economical point of cut-off?

Professor. Well ———.

Doe. Never mind, it is not my object to embarrass your theories, but to select an engine.

Professor. But I question the accuracy of your estimate for extra cost of fuel.

Smith. Here are some figures taken from our actual practice.* To deliver 150 horse-powers at 80 lbs. boiler pressure, requires, at $\frac{1}{4}$ cut-off 17·7 lbs. of steam per horse-power per hour; at $\frac{1}{6}$ cut-off, 18 lbs. of steam; at $\frac{1}{10}$ cut off 25·3 lbs.

Doe and *Professor.* What! more steam for the shorter cut-off. Let us see the figures. (Musingly) that is so.

Doe. Then even the cost of steam is in favor of the smaller engine.

Smith. The difference is chiefly due to the condensation of the steam in the cylinder. Where expansion is 10 or more the condensation must be considerable, and I would not be surprised to learn that it even exceeded the largest figures here given.

Professor. This looks suspicious; for, theoretically, the engine of my selection should require only 13·8 pounds, and the smaller one 15·6 pounds.†

Smith. I have here some tables of condensations,‡ giving the latest, and perhaps the most reliable information on this point. The percentage of the whole consumption of feed-water at $\frac{1}{20}$ cut-off is 42; at $\frac{1}{15}$, 34; at $\frac{1}{8}$, 29; at $\frac{1}{6}$, 26; at $\frac{1}{4}$, 24. Will the Professor calculate what the actual consumption should be according to these figures?

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* Circular of Buckeye Engine Co.

† *Idem.*

‡ Barrus on Tabor's Steam Indicator.

Professor (figuring). At $\frac{1}{10}$ cut-off, $13{\cdot}8\left(1+\frac{34}{100-34}\right)=20{\cdot}91$ pounds; at $\frac{1}{5}$ cut-off, $15{\cdot}6\left(1+\frac{26}{100-26}\right)=21{\cdot}07$ pounds. This gives 20·91 pounds for the larger engine, and 21·07 pounds for the smaller; figures very different from those produced by Mr. Smith, and favorable to the larger engine.

Doe. How much will the difference amount to per year?

Professor. (21·07 — 20·97 = 0·16) × 150 HP × 10 hours × 300 days ÷ 1,000 = 72 thousand pounds of steam, which, at 25 cents per thousand, will be $18 per year. But the authors differ considerably in regard to the results of condensation. I see in Barrus' book, from which you took the above figures, that the difference in favor of the larger engine is for $\frac{1}{10}$ and $\frac{1}{5}$ cut-off, respectively, 0·97 of a pound of steam per horse-power per hour, making a difference of about $110 per year from this cause only.

Doe. I see that there is a possibility of considerable loss from this cause, but the most unfavorable showing does not equal the $160 saved in "constant charges," and I have decided to order the smaller engine.

Professor. But does not your view of the case warrant you in ordering a still smaller one?

Doe. Possibly; but the practical result is this: you selected an engine according to your theory; Mr. Smith selected another according to his general practice, and, by the help of both of you, I have satisfied myself that Smith's is the more economical engine of the two for me to purchase for my business. If another size were selected, we would apply to it the same mode of reasoning, and ascertain if the money *saved* by the interest, repairs, etc., equaled that *lost* by fuel and other conditions; and, by trying a few engines in this way, we would at last find one which, for such a cut-off as would deliver the required horse-powers with the given steam pressure, would be the most economical for me to purchase, considering first cost, cost of fuel and constant charges. Such an engine is said to have "the most economical point of cut-off." Your method, apparently, does not contemplate this process, and evidently needs revision.

The Professor retires, disappointed at the result. His rule had not purchased the engine, and his theory had received some fatal blows.

On his way he met a friend who had given some attention to the problem of the cut-off, and they entered into a conversation.

Professor. Would you believe it? John Doe has just purchased an engine for his shop that will cost him, say $100 per year more for steam than it would for a certain other engine which I selected for him.

Friend. I thought John Doe was a shrewd business man. How did it happen?

Professor. Smith convinced him that it would be more economical for him in the long run.

Friend. These salesmen are sharp; but what arguments did he use?

Professor. Why, he convinced him that his saving in interest, repairs, deterioration, oil and wages would exceed the extra cost for fuel.

Friend. Was not that correct?

Professor. Really, I could not gain-say it, with the conditions and figures they gave; but it gives a very different value for the cut-off than found by my theory. I have insisted that the "constant charges" disappear in determining the proper point of cut-off; but according to their showing they have considerable influence. Doe's boilers are already set, and, fortunately for him, they prove to be large enough to furnish the required steam economically. Had they been much smaller, he would have been obliged to have taken the engine of my selection, or expended all he saved on the engine in putting in larger boilers.

Friend. Exactly, and I have noticed your difficulty on this point. The problem is one of maxima and minima, and the fact is you have assumed, beforehand, certain quantities as constant, which, in the process of designing, are variables; and these you enter in your function before seeking the maximum, which, as a mathematical operation, you know, even better than I, to be erroneous, and will fail to give the true maximum. Your admission just made in regard to the boilers is fatal to your theory; for it shows that, in designing an entire plant, the most economical point of cut-off will involve the first cost of the boilers while you declare it to be independent of all such considerations. You have just seen, also, that after they are set, it has had its influence in selecting the engine. Again, you say "C = the constant charges in dollars and cents, and is assumed to remain constant after once being fixed upon." (Feb., 1884, p. 85.) Please inform me

how you could fix the charge for interest before you knew the cost of the engine.

Professor. I assumed that "the constant charges may be determined regardless of the cost of steam." (Feb., 1884, pp. 83 and 84.)

Friend. The answer is rather evasive; for I referred to the cost of engine—not of steam; but, as they are in a measure related, I will say that your assumption is not admissible. The smaller the engine, the less the first cost, and the interest on the money correspondingly less; while the cost for steam will be more so that this quantity—which you have considered constant—*varies* inversely with the cost of steam. Similarly, the cost for repairs and deterioration *vary* in the same sense but not in the same ratio, nor necessarily according to the same law. After the engine is set, the interest is *fixed*, whether the engine be run 200 or 300 days, or if it be run night and day; while the repairs will depend chiefly upon the amount it is used. I am aware that the problem involving such contingencies cannot be solved, but I mention them to show more clearly, if possible, that the proper point of cut-off is not independent of these things.

Professor. But you must admit that after the engine is set, all the charges which can be considered constant are fixed, and must be some "fraction of the mean effective pressure." That John Doe, *after* "his purchase and arrangements are made, has done with constant charges, and must look to economy of steam as the only means of saving money." (Feb., 1884, p. 83.)

Friend. I think our friend, John Doe, will not agree with you. He will inform you, even after his engine is set, that he "has not done with constant charges," that he finds a continual draft on his purse for interest, repairs, oil, insurance and taxes; and that he has no commendation for the man who fixes one dollar upon him unnecessarily. True, if he has been mislead in his purchases, and been made to pay an unnecessary amount in first cost, he will be obliged to endure it; but it is wiser to consider all these elements *before* the purchase. But your plea, that they become fixed *after* the purchase, is fallacious from a mathematical point of view; you might as well argue that the cut-off becomes *fixed* after you have found it, or that any other element is fixed. It is unnecessary to argue this point; it is only necessary to convince you that these so-called "constant charges" are variables in the process of designing, to cause you to abandon your rule, giving as it does a cut-off of $\frac{1}{10}$ to $\frac{1}{20}$, which you have insisted up to the present

time to be "practically accurate within the widest range," after establishing certain relations in regard to the steam. (Jan., 1884, p. 1.) When thus convinced, you will admit that "economy of fluid" is only one element of the general problem of economy; that by saving steam *only*, you will lose money. You will then see that your arraignment of living and deceased writers is premature, to say the least. You will also find that you expose yourself to attacks by critics; for instance, you stated that "the volume of the cylinder is dependent upon the constant charges," that "the cut-off is independent of those charges"—conditions incompatible; that whenever it is possible to fix the constant charges on and to design an engine regardless of its horse-power, then will the proof lack in generality" (p. 82), an admission which is fatal to your theory. For in the next paragraph you assert that several of the charges are independent of the horse-power within certain limits, and that for these at least the proportion on page 86 cannot be true; but, even if true for these, the same proportion cannot be true for the other charges, as interest, for instance.

Finally, you are already aware that Rankine made the most general solution yet attained, in which the several elements above mentioned are treated as variables; a special case of which includes your problem of "economy of steam only," and of which the general case includes both the designer's and owner's problems. You are also aware that Denton and Wolff unearthed this solution, so to speak, enlarged upon and amplified it, by discussing it in their papers and applying the method to a large number of existing engines;† and, although it is not claimed by these writers that the method possesses mathematical exactness, yet it is claimed that the defect in the process lies chiefly in the data rather than in the method. In view of these facts, you may at last consider it advisable to take to yourself the advice you have given to another, and "give the most careful consideration to the point at issue."

[NOTE.—Professor Rankine stated his problem thus: "By increasing the ratio of expansion in a Cornish engine, the quantity of steam required to perform a given duty is diminished; and the cost of fuel and of the boil-

† Transactions of the American Society of Mechanical Engineers, 1881, page 147 and page 281; republished in the *American Engineer*, 1881, June, July, August and November; and in the Transactions of the Institution of Civil Engineers (London), 1881–82, Vol. LXVIII, Part II, p. 75; Part III, p. 44.

ers is lowered. But at the same time, as the cylinders and every part of the engine is increased, must be made larger to admit of a greater expansion, the cost of the engine is increased. It thus becomes a problem of maxima and minima to determine what ratio of expansion ought to be adopted under given circumstances, in order that the sum of the annual cost of fuel, and the interest of the capital employed in construction may be the least possible as compared with the work done."—*Phil. Mag.*, 1854, (2), p. 345.

This problem Rankine solves in his usual masterly manner, and then shows how to design a 100 horse-power engine, according to his method, making the cost of engine and of boilers variable; deducing the point of cut-off, the area of the piston, and mass of the boilers. In this he uses the graphical method. In the owner's problem, the cost of the plant being known, the interest will be known, and the cost of fuel and point of cut-off are the variables, but the *method* of finding the point of cut-off is the same as before.]

Stevens' Institute of Technology, Hoboken,
February, 15, 1884.

Critical Point of Liquefiable Gases.—Jamin believes that gases are liquefiable at every temperature, when the pressure is sufficient. He defines the critical point as the temperature at which a liquid and its saturated vapor have the same density; but the general law of vaporization is not suddenly interrupted; the liquid continues to be at its point of ebullition and maximum tension. If it ceases to be visible it is because it is mixed with the gas, in which it swims on account of the equal densities, and when the temperature continues to increase the tension also increases until the liquid is entirely volatilized. Then the space ceases to be saturated and there is only a dry vapor, or gas, far removed from its point of liquefaction. In general, a saturated vapor is distinguished from its generating liquid by its smaller density and its latent heat; in the present case the densities are equal and there is no latent heat, since the volume does not change and there is no work of expansion. Hence, at the critical point, nothing distinguishes the liquid from its vapor, neither the tension, the density, the constituent heat, the appearance, nor any other known property. Jamin submitted these views to Cailletet, with the statement that if his hypothesis was true the liquefaction would be retarded by replacing the air in his mixture of air and carbonic acid by some lighter gas, for instance, hydrogen. Cailletet performed the experiment and found that the results were such as had been predicted.—*Comptes Rendus*, May 21, 1883.

THE ALLEGED "REMARKABLE ERROR IN THE THEORY OF THE TURBINE WATER WHEEL."

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Though it can hardly be urged that any theory of turbines has been confirmed by experiment with precision, or has even had more than a slight influence on their design and operation, it is nevertheless a matter of importance and justice that the "common theory," presented by Weisbach and Bresse, should be recognized as employing sound principles of dynamics in obtaining results from its fundamental hypotheses, whether the latter are perfectly realized in practice, or not. Let us undertake a brief sketch of this theory, omitting all considerations of frictional and other resistances, for the sake of simplicity. Its fundamental hypotheses are: "steady motion" of the water, uniform angular velocity of the wheel, "flow in plane layers," filled channels, "full gate," and no shock on entering the wheel (*i. e.* at entrance the relative velocity of the water must be tangent to the wheel float; otherwise there would be an abrupt change in the absolute velocity, rendering incorrect the assumption to be made here that the internal pressure, p_1, at the beginning of the wheel channels is the same as that toward the extremity of the guide passages).

The relations holding good in these hypotheses between the quantities involved are stated in equations (1) to (6) inclusive; in which Q denotes the volume of water used per second; h, the height from head to tail water; h_2, the mean depth of wheel channel below surface of tail water; F, F_1, and F_2, the total cross sections of the ends of guide passages, and at entrance, and at exit, of wheel channels, respectively; c_1, r_1, v_1, the relative velocity of water, the wheel radius, and the wheel rotary velocity at the entrance of a wheel channel: c_2, r_2, v_2, corresponding quantities at exit of wheel channel: p_1 and p_2, the mean internal water pressures at entrance and exit of wheel; w, the absolute velocity at exit; γ, the weight of a cubic unit of water; b, the height of a water barometer; and g, the acceleration of gravity. We have then: energy transmitted to wheel:

$$= Q\gamma h - Q\gamma \frac{w^2}{2g}. \tag{1}$$

Relation holding good for the *fixed* channels between the head water

and the extremity of guides where the absolute velocity is c, (Bernoulli's theorem):

$$\frac{c^2}{2g} + \frac{p_1}{\gamma} = h + h_2 + b. \tag{2}$$

Continuity of flow, channels filled:

$$Q = Fc = F_1c_1 = F_2c_2. \tag{3}$$

Trigonometrical relations in the parallelograms of velocities at entrance and exit from the wheel. (4)

The proportion $v_1 : v_2 : : r_1 : r_2$. (5)

Relation between the relative velocities and internal pressures of the water, and the rotary wheel velocities at entrance and exit of a wheel channel $\left(\text{assuming } \frac{p_2}{\gamma} = h_2 + b\right)$, viz.:

$$\frac{c_2^2}{2g} + h_2 + b = \frac{c_1^2}{2g} + \frac{p_1}{\gamma} + \left[\frac{v_2^2 - v_1^2}{2g}\right] \tag{6}$$

Weisbach's presentment of this last relation is marred by the statement that it is connected with some mysterious "centrifugal force." He does not prove equation (6), but thinks it sufficient to base it upon the result

$$c_2^2 - c_1^2 = v_2^2 - v_1^2 \tag{7}$$

obtained in the problem of a rotating top or disc, in a channel on whose surface a small solid body is free to move without friction (or gravity, if the groove is horizontal). (Vol. I, §§ 303 and 304.)

Equation (7) is correct, and will be demonstrated further on, as well as (6), which does not depend directly on (7), as Weisbach implies.

An article by Mr. Frizell in the number of this Journal for August, 1883, entitled "Remarkable Error in the Common Theory of the Turbine Water Wheel," by implication denies the truth of (7) on account of an absurdity in Weisbach's method of demonstrating it. The ideas and method of Weisbach's treatment of that problem have already been referred to as absurd, in an article by the present writer, prepared five years ago (see p. 215 of Van Nostrand's Eng. Mag. for March, 1880); but it is clear that Mr. Frizell does not appreciate all the absurdities of the situation, since he upholds Weisbach's ideas in the particular case where the groove is radial.

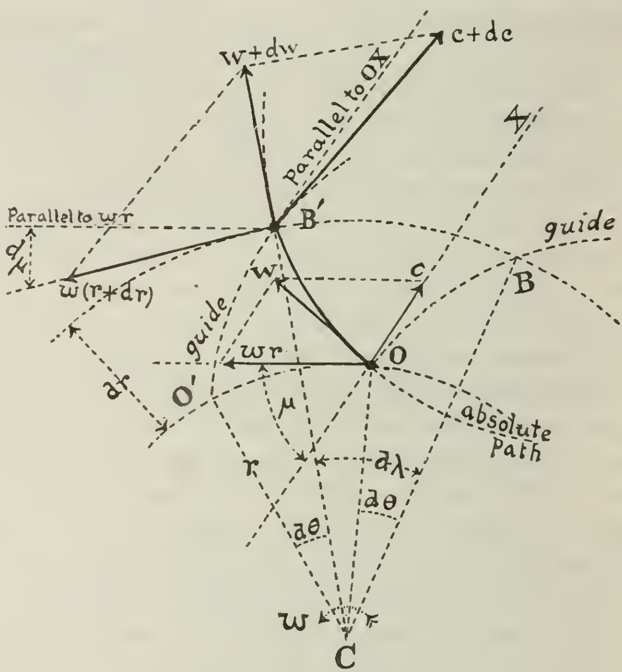
Since Weisbach's method of demonstrating equation (7) is certainly to be condemned, let us apply to the problem of the disc correct prin-

ciples of dynamics (viz., Newton's laws), employing no conceptions beyond those of time, space, mass, and force, omitting all use of the compound ideas of work and energy, which always owe their meaning, and the means of verifying results obtained by them, to the former conceptions. As a preliminary, however, it will be useful to glance at a more familiar and simple problem in which the use of the terms "centripetal" and centrifugal" have no ambiguity.

If a particle, with some original absolute velocity w, be guided in a curve by a *fixed* groove or channel, without friction (or gravity), its absolute velocity remains unchanged in amount, though continually altered in direction. The only force acting on it is the pressure of the side of the groove, and is always normal to the path. As is well known (Rankine), the pressure of the guide against the particle is called the "centripetal" or "deviating" force, coming into play when we consider the particle and its motion, and acting *toward* the centre of curvature; while its equal and opposite (according to Newton's law of action and reaction), the "centrifugal" force is the pressure on the fixed guide, directed away from that centre, and taking its place with the other forces which strain the guide. Hence it is improper and confusing to say that the particle is acted on by the centrifugal force, as so many writers persist in doing, among whom are Weisbach and Deschanel; while Rankine and Ganot are careful to give no such impression. (Compare the differing methods and phraseology of Deschanel and Ganot in explaining the apparent diminution of gravity due to the earth's rotation. The mistake in question is similar to the one which would be made in saying that an ordinary bridge truss is acted on by a *downward* force at its points of contact with the piers; a mistake, however, never made; the occurrence of the other is therefore surprising.

Next, suppose the curved groove or channel to *rotate*, with a uniform angular velocity ω, about a fixed axis perpendicular to its plane, while the particle is passing through it. Since there are now, at any instant of its progress, *three* different centres to be considered, viz., the fixed centre of the disc, the centre of curvature of the groove, and that of the absolute path, for the point of contact, it is best to drop all such terms as centrifugal, or centripetal, force, or "centrifugal action," as their use in this connection tends to ambiguity and vagueness. As before, the only force acting on the particle (gravity is eliminated, since the disc is horizontal) is the pressure of one side of the guide

against it, and must be normal to the guide curve (there being no friction), *i. e.*, is directed toward the centre of curvature of the latter. This force, not being in general normal to the absolute path, causes a continual change in the absolute velocity. The absolute velocity w, is the diagonal formed on the rotary velocity $v = \omega r$ of the point of contact of guide, and c the velocity of the particle relatively to this



point of the guide, r being the radial distance of the particle, at any instant, from the centre of disc. It is required to find the law of variation of c, the relative velocity, its value being c_1 at a definite point of the groove where $r = r_1$.

Let OB' represent any element, described in a time dt, of the absolute path; $\mu =$ the angle between the rotary velocity ωr and the guide tangent at O. During the time dt the angular motion of the disc is $d\lambda$, the relative angular motion of the particle, $d\theta$; r has increased an amount dr. From kinematics and trigonometry the following relations are evident:

$$OB, \text{ or } O'B', = cdt$$

$$\omega = \frac{d\lambda}{dt} \tag{8}$$

$$cdt \sin. \mu = dr \tag{9}$$

$$cdt \cos. \mu = r\, d\theta \tag{10}$$

and
$$d\mu = -(d\lambda - d\theta) \tag{11}$$

Since the only force acting on the particle at O is perpendicular to OX (call this the axis X), it is incapable of affecting the X component of w, *i. e.*, w_x, which = the algebraic sum of the X components of c and ωr. Hence we must have

$$\frac{dw_x}{dt} = \text{zero}, \; i.\,e., \; \frac{d\,(c - \omega r \cos. \mu)}{dt} = 0$$

or, in detail, ω being the only constant,

$$\frac{dc}{dt} - \omega \cos. \mu \frac{dr}{dt} + \omega r \sin. \mu \frac{d\mu}{dt} = 0$$

Substituting from (11), we have

$$\frac{dc}{dt.} - \omega \cos. \mu \frac{dr}{dt} + \omega r \sin. \mu \frac{d\theta}{dt} - \omega r \sin. \mu \frac{d\lambda}{dt} = 0 \tag{12}$$

Transforming the second term of (12) by the aid of equation (9); the third by (10); the fourth by (8), then by (9); we finally obtain

$$\frac{dc}{dt} - \omega c \cos. \mu \sin. \mu + \omega c \cos. \mu \sin. \mu - \frac{\omega^2 r dr}{cdt} = 0 \tag{13}$$

$$i.\,e., \; \frac{cdc}{dt} = \frac{\omega^2 r dr}{dt}; \text{ whence } cdc = \omega^2 r dr,$$

which integrated between corresponding limits, c_2 and c_1 for c, r_2 and r_1 for r, ω being constant gives

$$\frac{c_2^{\,2} - c_1^{\,2}}{2} = \frac{\omega^2 (r_2^{\,2} - r_1^{\,2})}{2} \tag{13a}$$

i. e., $c_2^{\,2} - c_1^{\,2} = v_2^{\,2} - v_1^{\,2}$, *Q. E. D.*; a result independent of the form of the guide.

(The foregoing demonstration is a reproduction, in a more compact form, of a portion of the article referred to in Van Nostrand's Mag.)

The errors in Weisbach's treatment of the problem can now be better appreciated. He makes the pressure or force acting on the particle at any instant radial to the disc axis, whatever the form of the

groove, instead of normal to the groove, and assigns to it a value $\omega^2 Mr$, also independent of the form of groove, whereas the true value of that pressure is

$$N = M\left[\frac{c^2}{\rho} + \omega^2 r \cos. \mu - 2\omega c\right] \tag{14}$$

M denoting the mass of the particle.

(From the same article in Van Nostrand's Mag.) In (14) ρ is the radius of curvature of the guide curve at the point of contact. If the groove were radial to the disc, μ would $= 90°$ at all points, $\rho = \infty$ hence the pressure against the particle is numerically $= 2M\omega c$, and is perpendicular to a radial direction. Again, if the groove were circular and concentric with the disc, and the particle stationary in space, we have at every point of groove, $c = \omega r$, $\mu = 0°$, and $\rho = r$, whence N reduces to zero, as it should, since there is no action between the disc and particle. Also, with a circular groove, concentric with the disc, the particle having an absolute velocity w, we have, as before, $\mu = 0°$ and $\rho = r$, while $c = \omega r - w$; which reduces N to $Mw^2 \div r$, the "centripetal force," or pressure, from a fixed circular guide; which again testifies to the correctness of the expression for N in (14); for in this case, evidently, the constraint of the groove on the particle is the same as if the former were fixed.

Weisbach's expression $\frac{G}{g} \cdot \frac{c_2{}^2 - c_1{}^2}{2}$ which he calls "energy stored," and in which c_2 and c_1 are relative velocities, does not represent work done upon the particle, since (see (13*a*)) it is independent of the form of the path between the initial and final circumferances, whereas the pressure N is not. For example, it would be possible to so design the groove as to allow the particle to traverse the disc without contact with either side of the groove, hence without pressure, and rectilineally. In this case the particle has "true angular velocity" about the disc centre, but what becomes of either Weisbach's, or Mr. Frizell's "centrifugal force?" The equation of such a curve is determined from the condition $N = o$ at all points. In their demonstration Weisbach and his copyists were probably misled by the brevity and simplicity of its algebraic matter and the current misuse of the term "centrifugal force."

Resuming the "common theory" of the turbine, it is hardly sufficient to base (6) on (7) by mere inference. The variation of c, the

relative velocity of water traversing and filling a uniformly rotating passage or pipe, when "steady motion" (or a "state of permanency) is once established, is, however, easily deduced from the same figure. By "steady motion" it is implied that the mean internal pressure and velocity of the water at any section of the passage are always the same for that part of the passage while the flow is going on; *e. g.* the same pressure which acts on a retarding force at one end, B, of a lamina whose thickness $= OB = cdt$ (and whose base is F, normal to OB) becomes an accelerating force for it when the base, originally at O, has arrived at B', dt having elapsed. Let $p =$ the mean internal water pressure at O, then $p + dp =$ that at B (or B'). Hence, since the pressure on the edges of the lamina are all normal to OX, the sum of the X components of all the forces acting on the lamina is $= Fp - F(p + dp)$ *i. e.* $= -Fdp$, and this must equal the mass, $\frac{Fcdt\gamma}{g}$, multiplied by the X acceleration, *i. e.*, by $\frac{dw_x}{dt}$ which we have already in the left hand member of equation (13).

Therefore,

$$-Fdp = \frac{Fcdt\gamma}{g}\left[\frac{dc}{dt} - \frac{\omega^2 rdr}{cdt}\right];$$

whence

$$\frac{1}{g}cdc - \frac{\omega^2}{g}rdr = -\frac{1}{\gamma}dp,$$

in which the variables are separated. Integrating between any two points of the channel, as 1 and 2, remembering that γ, ω and g are constant, and that $\omega r = v$, we have, after transposition,

$$\frac{c_2^2}{2g} + \frac{p_2}{\gamma} = \frac{c_1^2}{2g} + \frac{p_1}{\gamma} + \frac{v_2^2 - v_1^2}{2g} \qquad (15)$$

Hence equation (6) is correct.

As to testing the "common theory" as here presented, by the valuable experiments of Mr. Francis on the Tremont turbine, it must be remembered that two of the hypothesis on which it rests are "full gate," and "no shock" at the entrance of a wheel channel.

Experiments Nos. 20, 21 and 22, realize the first completely, and the second very nearly; for in Exp. 21 the discharge being $Q = 139{\cdot}90$ cubic feet per second, we have $c = Q \div F = 21{\cdot}42$ feet per second, and c cos. $\alpha = 19{\cdot}08$, which is very near the value for v_1 (19·13) found

by experiment. (The value $a = 27°$, the angle between c and v_1, was obtained from the drawing in Mr. Francis' book, and since the entrance float-tangent is perpendicular to v_1, we must have $v_1 = c \cos. a$ if c_1 is to follow that tangent.) Proceeding, then, with Exp. 21, as almost the only one fitted for the purpose, we substitute the values $F = 6{\cdot}53$ square feet; $F_1 = 19{\cdot}78$ (partly from the drawing); $F_2 = 7{\cdot}65$; $v_1 = 19{\cdot}13$ feet; $v_2 = \frac{4{\cdot}06}{3{\cdot}38} \times v_1 = 1{\cdot}201 \times 19{\cdot}13$ (*i. e.* v_2 is taken at the middle of the cross section of an exit orifice, as it should be); $h = 12{\cdot}899$; and $g = 32{\cdot}2$; in the formula

$$\frac{c_2^2}{2g} = \left[h + \frac{v_2^2 - v_1^2}{2g}\right] \div \left[1 + \left(\frac{F_2}{F}\right)^2 - \left(\frac{F_2}{F_1}\right)^2\right] \qquad (16)$$

obtained by elimination between equations (2), (3) and (6), and obtain $c_2 = 21{\cdot}16$ feet per second; and therefore the discharge $= F_2 c_2 = 7{\cdot}65 \times 21{\cdot}16 = 161{\cdot}87$ cubic feet per second. The observed discharge was $139{\cdot}90$, which is therefore $13\frac{1}{2}$ per cent. less than the theoretical; but when it is remembered that in this presentment *no allowance whatever* has been made for "losses of head" due to any cause, nor for any deviation from the hypothesis at the base of the theory, this result is not to be regarded as unsatisfactory, nor as indicating error in the application of analysis in developing results from the hypothesis.

There is considerable variation in the sizes of the various cross sections, as in Venturi's tube, but the discrepancies (some of which are as high as 80 per cent.), recorded in Mr. Francis' book, between experiment and theory, in the case of the latter apparatus, have not as yet led any one to assert that the simplest formula of hydraulics, $v = \sqrt{2gh}$, is not "well founded in theory."

Ithaca, December, 1883.

Galvanizing of Brass and Iron.—Neujeau and Delaite, of Liége, have contrived a galvanizing process for objects of large dimensions or impossible to be removed, and which, consequently, cannot be plunged into a bath of melted zinc. The process is also cheaper than ordinary galvanizing and equally durable. Finely powdered zinc is mixed with oil and siccative. A varnish is thus formed, which may be applied with a brush in the ordinary manner. A single coat is often sufficient, but it is better to use two. The objects are then of an iron-gray and they can be left in that condition or bronzed or painted.
Chron, Industr., April 8, 1883. C.

PETROLEUM AS A SOURCE OF EMERGENCY POWER FOR WAR-SHIPS.

By N. B. Clark, Passed Assistant-Engineer, U. S. N.

A war-ship requires two different rates of speed, one, which for convenience of expression, may be called passage power, would be used on all ordinary occasions when steaming from port to port; and the other, emergency power, required for chasing an enemy or escaping from a superior force, when a high rate of speed will be necessary.

The requirements of a cruising war-ship and a commercial vessel making regular passages from port to port are entirely different. The passenger or fast freight steamer needs sustained high speed to enable her to make trips in the shortest time possible and with the utmost economy of fuel in order to pay a profit to her owners; while the war-ship does not need sustained high speed, but requires a still higher rate of speed to be used for only a few hours at a time in an emergency, it being admissible to attain this extreme high speed at an extravagant cost of fuel, as economy of fuel can only be attained by great weight of machinery, involving increased displacement.

It was the experience of officers who served on the vessels blockading the southern coast that if a blockade-runner was sighted early in the day her capture was almost a certainty notwithstanding the assumed superiority in speed of that class of vessels; but if the vessel was not sighted in time to admit of her capture before night, darkness frequently enabled her to elude her pursuers, even though they possessed superior speed.

As darkness favors the weak in eluding pursuit, commerce destroyers should be provided with high emergency power to enable them to capture their prizes while daylight lasts.

The passage power of a war-ship should be so designed as to be capable of being used with great economy of fuel, enabling the vessel to steam great distances, and to keep the sea for lengthened periods of time; while on the other hand, to avoid excessive weight of machinery, economy of fuel would be a matter of secondary consideration when using the emergency power, which would be but rarely called into action, and then for only a short period of time, and therefore would not warrant the encumbrance of a great weight of machinery.

The passage power of a war-ship may be sufficient to drive the ship

nine or ten knots per hour, while her emergency power should be equal to the attainment of double that speed. This would require the emergency power to approximate to eight times the passage power.

Such enormous power cannot be attained in a vessel of ordinary size, burning solid fuel on grate bars with natural draught, designed for economy of fuel, unless the entire hull of the ship is filled with boilers, absorbing the greater part of the displacement by the weight of the engines, boilers and fuel, thereby depriving the vessel of offensive and defensive power.

It has been proposed to construct such vessels, in which all other desirable qualities would be sacrificed to extreme high speed, but the propriety of such a course may well be questioned. High speed alone, without a due complement of defensive and offensive power, would simply enable a naval commander to chase down an enemy which he dare not fight, a feat by which he would gain only negative renown.

Although it is impracticable to construct a vessel of ordinary dimensions, combining extreme high speed with due defensive and offensive qualities, with motive power derived from the combustion of solid fuel or grate bars in ordinary boilers with natural draught, yet, with liquid fuel, such a speed can be developed in a vessel of very moderate displacement.

In boilers for consuming solid fuel the steam generating power is measured by the area of the grate surface, and even when the draught is forced, the amount of heat produced from such fuel is much less than the heating surface will absorb, provided the heating surface is the maximum the boilers will contain.

Solid fuel is burned only from its surface by the erosive action of diluted oxygen, consequently the combustion of such fuel is slow and torpid compared with liquid fuel, which can be converted into a gas with rapidity and facility.

Ordinary marine boilers for consuming anthracite coal have from 20 to 25 square feet of heating surface to the square foot of grate, and such boilers are found to give good results with solid fuel, as the heating surface is sufficient to absorb all the heat that can be generated from such fuel; but it is possible to construct tubular boilers for burning petroleum having 75 square feet of heating surface to the square foot of grate.

With such boilers having the liquid fuel sprayed into their furnaces by jets of superheated steam or hot air, the steam generating power

would be measured by the largely increased extent of the heating surface, and not by the limited area of the grate, as the fuel could be consumed at a rate fully up to the capacity of the heating surface to absorb the heat generated by its combustion.

In a properly constructed furnace, petroleum can be burned entirely without smoke, the combustion being complete, and its practical calorific value has been proved to be fully equal to three times its weight of the best coal.

A high authority on engineering subjects, *Molesworth's Pocket-book*, p. 460, revised edition, gives the following account of the method of burning petroleum, as practiced in England, with its advantages as a fuel :

" No alteration of the ordinary furnace or grate is necessary. For burning oil the grate bars are covered with slabs, overlaid with fine cinders, and the ash-pit doors closed. The oil fell vertically, a jet of superheated steam met it, and turned it into vapor, which then took fire and was consumed in a perfect manner.

" The water evaporated amounted to 20·8 pounds per pound of oil consumed. The average result of several days' experiment was 19½ pounds of water evaporated per pound of oil.

" With the best Aberdare coal the same boiler evaporated 6½ pounds of water per pound of coal consumed. The advantages claimed for liquid fuel in seagoing vessels are :

" 1st. A reduction of weight of fuel.

" 2d. A reduction of bulk of fuel.

" 3d. A reduction of fire-room force in the porportion of 4 to 1.

" 4th. Prompt kindling of fires.

" 5th. The fires can be extinguished instantaneously.

" 6th. Capability of stowage in place of water ballast, by which it may be replaced as consumed, and great facility for taking in rapidly.

" 7th. Its cleanliness, and freedom from ashes cinders, etc.

" 8th. The absence of the loss of heat due to the frequent opening of furnace doors.

" 9th. The ability to command a more intense fire, and management of temperature without forced draught.

" 10th. Facility for perfect combustion and rapidity of raising steam.

" 11th. Freedom from smoke."

Mr. Henry F. Hayden, of Washington, D. C., has recently obtained

several United States patents on furnaces for an improved method of burning hydrocarbons, in which the liquid fuel is sprayed into the furnace by a jet of steam superheated to 1,200° Fahr., and having the air-supporting combustion heated to 800° Fahr. By this method it is claimed petroleum will give a calorific value greater than the above estimate.

In order to show the merits of petroleum as a source of emergency power we will take for illustration the proposed 3,000-ton cruisers, in which it is understood 1,200 tons of the displacement is allotted to steam machinery and fuel, the weight of the machinery being 700 tons, and the coal 500 tons.

If the boilers of these ships were specially designed to burn petroleum as an emergency fuel, their steam generating power could be doubled, while their weight could be decreased 150 tons.

The same boilers could also be used to consume anthracite coal with great economy when the ship was using her passage power.

If instead of carrying 500 tons of coal, the ship was equipped with 260 tons of coal, and 80 tons of petroleum stored in the cellular bottom, aggregating 340 tons, she would have her full complement of fuel, the equivalent of 500 tons of coal, thereby effecting a saving in weight of 160 tons.

If this aggregate weight of 310 tons, saved from boilers and fuel, was put into deflecting armor and heavy guns, in addition to the weights already allotted for that purpose, it would produce vessels of moderate size and cost, having a greater emergency speed than any existing commercial vessel, and having offensive and defensive powers equal to a heavy iron-clad. Such a ship would combine all the desirable qualities of a light, rapid cruiser, and a heavy coast-defence vessel.

The reason why petroleum has not been used as a fuel in the merchant marine is on account of its cost, and it is not likely that it will ever be able to compete successfully with its powerful rivals, anthracite and bituminous coal.

The objection to the use of petroleum in the vessels of the navy is its assumed dangerous character, but it should be remembered that the same objection could be urged against gunpowder, and was strongly urged against the introduction of steam, notwithstanding which both gunpowder and steam have been introduced, and will be retained in spite of their dangerous character.

In regard to the dangerous qualities of petroleum it may be said, if

its storage and use were surrounded by the same safeguards and precautions as those we observe in the storage and use of gunpowder, it would not be found any more dangerous. Besides it should not be forgotten that fighting, the purpose of a war-ship, cannot be made a safe business. The chief danger from petroleum arises from the emanation of an inflammable gas which is given off at all ordinary temperatures, but with refined petroleum this gas is scarcely appreciable in quantity when the fluid is kept at the temperature of sea water, which could be accomplished by storing it in the double bottom of the vessel, and danger from an accumulation of gas in the petroleum tanks could be avoided by providing them with appropriate ventilating pipes, leading overboard, above the water line.

While the cost of petroleum will bar its use as a fuel in the merchant marine, its introduction as an emergency fuel for the navy would be a measure of great economy. In the navy the necessities of the service require a very large fire-room force, fully 33 per cent. of which may be denominated emergency men, whose services might be dispensed with except when the ship is using her full steam power.

With petroleum as a source of emergency power the services of these extra men could be dispensed with, and the cost of their pay, rations, etc., would far more than compensate for the difference between the cost of coal and petroleum, as the pay, rations, etc., of the emergency men would be continuous, while the extra cost of the emergency fuel would only have to be borne for short durations of time at long intervals.

One advantage to be derived from the use of petroleum as a source of emergency power is that it will enable us to retain anthracite coal as the standard fuel of our navy, otherwise we will be forced to use bituminous coal in order to compete in speed with the ships of other nations.

It is proposed to use anthracite coal as the source of the passage power, reserving the petroleum for emergencies, the same boilers serving for each, but of course the petroleum could be utilized for the lower rate of speed should necessity require it.

Numerous trials of single and twin screw ships of the British navy prove that twin screws utilize 11 per cent. more power in propelling the ship than single screws; this is no doubt due to the greater immersion of the effective area of the twin screws. The principal source of loss with the screw propeller is from skin friction, which is

constant at all depths of immersion, while the propulsive efficiency increases with the depth of immersion. As twin screws give an increased efficiency of 11 per cent. over single screws, it is highly probable that triple screws would show a greater efficiency than twin screws, as, owing to the deeper immersion of the shafts, a less area of blade would give an equal propulsive efficiency, and if there was less area of blade there would be less loss from skin friction, and consequently a greater proportionate efficiency from the power applied.

The application of two or more screws would result, not only in a greater economy and efficiency of the power applied, than can be obtained from a single screw, but also in greater safety to the vessel, as it is not probable that all the screws would be disabled at one time. It would also admit of a further decrease of spars and sails, which would be a great encumbrance to a vessel chasing a more lightly sparred adversary, who would not fail to run to windward.

In order to avoid unnecessary friction it would be desirable to disconnect a part of the machinery when using her lower rate of power. This could be accomplished by dividing the motive power of a twin screw ship between two vertical cylinders, direct acting, compound engines, one double cylinder compound engine being set forward of, and the other aft of a driving pinion on the crank shaft of each screw, with a disconnecting device to each engine. This arrangement would permit either or both compound engines to be used for driving the screw. When running with the passage power only one engine would be used to drive each screw, when using the emergency power both engines would be connected. This type and disposition of machinery would be a great safeguard against accidents.

According to the able and very valuable report of Passed Assistant-Engineer John A. Tobin, U. S. Navy, published as House Executive Document 48, of the Second Session of the 47th Congress, the weight of the steam machinery of British merchant steamers is 480 pounds per indicated horse-power, and that of the vessels of the British Navy is 289 for the light steamer *Iris* and 360 pounds for other vessels; the weight of the steam machinery of the torpedo ram *Polyphemas,* having locomotive tubular boilers, is 180 pounds; and that of the two classes of light swift torpedo boats is 57·7 and 66·5 pounds per indicated horse-power.

This great reduction of weight is accomplished by the adoption of the locomotive tubular boiler, constructed of steel, furnishing steam of

high pressure to engines constructed of the very best material, to secure great strength with lightness, designed for extreme high piston speed, whereby great power is transmitted by very light machinery, the light machinery developing the great power by its rapidity of movement.

If the same general plan of steam machinery, in a modified form, were adopted for cruising vessels as that applied in the construction of torpedo boats, engines capable of transmitting the proposed emergency power of 18 or 20 knots per hour could be constructed within the limits of weight allotted for that purpose.

As the torpedo boats referred to, having a displacement of less than 100 tons, have attained a speed of 22·4 knots per hour on the measured mile, the emergency speed proposed will not seem unreasonable for a vessel of 3,000 tons displacement to those familiar with the law of speed in relation to dimensions as enunciated by the late Mr. Froude.

Nor would it be neccessary to build vessels so large as 3,000 tons displacement in order to combine high speed with great defensive and offensive powers, for extremely useful vessels could be constructed on 1,500 or 2,000 tons displacement, and as a cruiser can only be in one place at a time, no matter how great her size, and as a small vessel upon the plan proposed would be as effective as a commerce destroyer as the largest, it would seem to be the best policy to devote the small appropriations obtainable for the increase of the navy to the construction of a greater number of small ships, rather than to a less number of large ones.

Two such small swift cruisers of 2,000 tons displacement, armed with 10½″ pivot guns, mounted on vertical V shields, and with a proper complement of Hotchkiss revolving cannon, having an emergency speed of 18 or 20 knots, and provided with means of discharging rocket torpedoes, would be more than a match for an *Inflexible* or an *Italia*, as, owing to their small size and rapidity of movement, they would be very difficult to hit, either with shot or torpedo, while their unwieldy adversary would fall an easy victim to the latter weapon discharged from the two cruisers. The cost of construction and maintenance of one vessel of the *Inflexible* or *Italia* class will be found to be four times greater than that of two of the proposed cruisers of 2,000 tons displacement, while the fighting strength of the two latter combined, will be more efficient than that of one of the former.

CAST IRON IN STEAM BOILERS.

By S. Lloyd Wiegand.

[Read at the Stated Meeting, Wednesday, March 19, 1884.]

Immediately after the adjournment of the February meeting of this Institute, the drum having flat cast iron heads, was tested by hydrostatic pressure, for the purpose of ascertaining the strength of such heads.

The dimensions of the drum were four feet in length by thirty-six inches in diameter, the heads were of cast iron, of 18,000 lbs. tensile strength per square inch of cross section and one and fifteen sixteenths inches ($1\frac{15}{16}$) thick; in one head was a man-hole opening of about 10 x 14 inches, below it a feed inlet of two inches diameter and having a flange fastened thereon by four $\frac{5}{8}$ stud bolts and nuts; there were three openings for guage cocks and two for a glass water guage connection, such as is usual in cylinder boilers having this form of head. These openings were closed with screw plugs, the man-hole opening by a plate not planed, but simply cast with a flat bearing surface, and a gasket of vulcanized India rubber, interposed between it and the slightly raised bearing on the inner surface of the head which had been planed flat.

The other head was simply a casting without any perforations therein excepting of course the rivet holes in the flange.

This drum or cylinder was made by the same parties, Messrs. Sidebotham & Powell, of Frankford, who made the boiler which exploded in Gafney & Nolen's dye works, on Martha Street above Huntingdon Street, Philadelphia, on May 25, 1881, and the heads were cast from the same pattern, and fitted as nearly as they could be in the same way as the burst boiler head, the remaining parts of which were produced at the February meeting.

The test was made with a force-pump, having a $\frac{5}{8}$ in. diameter ram and two pressure guages, each provided with a maximum registering hand, and graduated in 25 lbs. divisions.

The following results were shown: at 425 lbs. to the sq. in. the longitudinal seam leaked just enough to show a wet line, as did also a small part of the seam between the cast iron head containing the manhole; at 550 lbs. the head cracked so as to make a noise, but showed very little leakage, the cracks being two radial ones from the man-hole opening, and one some 10 inches around the rim or flange, where it

joins the fillet uniting it with the flat part of the head; upon pressure being pumped up to 820 lbs. per square inch, about one-fifth of the head fell out, emptying the vessel of water in less than three seconds.

One of the guages used for this test was located on the highest part of the drum, and the other on the pipe close to the pump.

Up to the time of the breaking out of the piece, not more than a half pint of water escaped, although between 550 lbs. and 820 lbs. pressure, there were about thirty 6 inch strokes of a [illegible] in. diameter ram, made in about $\frac{3}{4}$ of a minute.

The feed water inlet, which was exactly the same as in the Gafney boiler head remains intact, and the fracture is through no other opening than the man-hole.

The back head of the drum expanded very nearly $\frac{3}{16}$ (within ·005 in.) of an inch, in the experiment, and resumed its former shape and appears to be unimpaired in strength.

It had been stated, in the course of the discussion of a paper on this subject, that such heads were unsafe at any pressure, and under a formula submitted on the blackboard to the Institute by a member, the ultimate strength of the head without openings in it, should have been between 25 and 30 lbs. per square inch.

The result of the test shows that such formula was entirely at fault, and that the strength of such structures is far in excess of any recognized factor of safety for the service to which they are applied, and most strongly suggests that the alarm attempted to be raised upon the subject was without reasonable foundation.

The propriety of experimentally ascertaining the properties of such structures, and the rules which should govern their construction and proportion, as now being done by the Committee of Science and the Arts, is obvious.

New Method of Insulating Telegraphic Wires.—C. Widemann, having applied the processes of Nobili and Becquerel, for coloring by means of alkaline plumbates and ferrates, observed that the pieces thus colored resisted all galvanic action and their surfaces no longer conducted the electric current. A wire of copper or brass, or even of iron, may thus be covered with an insulating layer, analogous to that of a coat of resin or of gutta percha. The insulation is complete, easily accomplished, and at a very moderate cost. It is also very durable and but slightly affected by the different atmospheric influences.—*Comptes Rendus*, Oct. 15, 1884.

HANGING THE LEVERS FOR INDICATION.

By Robert Grimshaw.

Where levers are used, whether slotted or with dipping link, to reduce the crosshead motion of horizontal engines, they may be (1) swung from the ceiling, (2) inverted and fulcrumed at the floor, or (3) fastened to the wall and swung horizontally.

The first method is usually the most convenient, as being more out of the way of the engineer and the operator. Besides this, it permits of the use of a long pendulum, and thus gives minimum distortion of the card.

We usually find engine rooms with ceilings which permit of easy attachment of the pendulum. We may divide wooden ceilings into three classes, (1) those in which the joists run parallel with the center line of the engine, (2) those having the joists crosswise of the engine axis, and (3) those which are ceiled with boards or with lath and plaster.

Where the joists run lengthwise of the engine, it is very easy to hang a pendulum. An ordinary stout lag screw is used, and the pen-

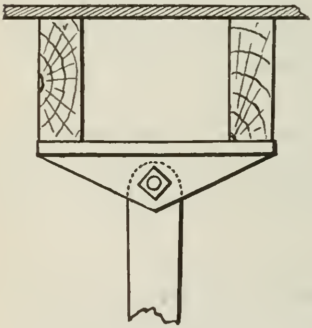


Fig. 1.

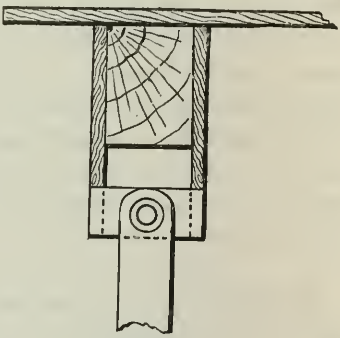


Fig. 2.

dulum put on that side of a joist which will bring the cord nearest in line with the indicator. By means of wooden washers between pendulum and joist and of projecting pins from the pendulum, the card may readily be "led fair," from the pendulum to the indicator. This is rendered easier by the fact that the indicator stem itself has a swivel

joint, giving it four or five inches of lateral adjustment when beside a horizontal cylinder, and more when on top.

Where the joists run crosswise of the engine, fasten across two of them, by lag screws, a wooden strip about 2″ × 3″, having another piece about 4″ × 1″ nailed to its edge; the latter piece having a ½″ hole for the pendulum pivot. (Fig. 1.) Or, nail a strip three inches by one on each side of the joist, and nail across between these a bridge-piece with ½″ hole. (Fig. 2.)

Where the ceiling is boarded, or lathed and plastered, fasten to it, by lag screws *or large gimlets*, the first angle piece recommended for crosswise joints.

Where there are sloping rafters instead of horizontal joists overhead, they generally run crosswise of the engine, and may have nailed across two of them a straddle-piece having its edge beveled to suit the slant of the roof.

There is one satisfaction about this case: it generally allows the use of a long pendulum, very easy to get in line with the instrument.

The straddle-piece may be either of scantling, as in Fig. 3, or of boards, as in Fig. 4.

Where ceiling attachment is impossible, as is sometimes the case by reason of steam pipes, etc., in the way, the inverted lever pivoted to

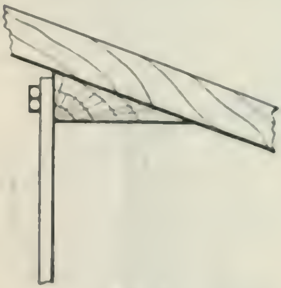


FIG. 3.

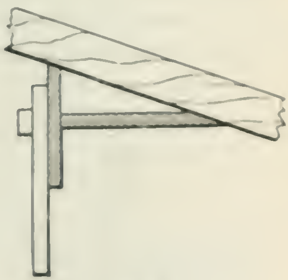


FIG. 4.

the floor is the handiest, if the floor happens to be of wood; but if of earth, cement, brick, stone, or iron, another method will have to be chosen.

But supposing the floor to be of wood, it is best to make a base piece, which can be fastened down snug against the bed plate of the engine, by screws or large gimlets. (Figs. 5 and 6.) A piece of 3″ × 4″

scantling 12 inches long, makes a good enough base piece, but care must be taken that the lever stands plumb.

An improvement in this gives lengthwise adjustment of the lever pivot, after the block is fastened down, so that the rig shall be in line with the crosshead attachment, if a slotted lever is used, or just the length of the dipping link in advance of it if the latter is employed. The pendulum, instead of being pivoted to the block directly, is attached to a right angle trough piece or ‾|, having in its upper side oblong bolt holes, to give it about an inch endwise adjustment. (Fig. 6.)

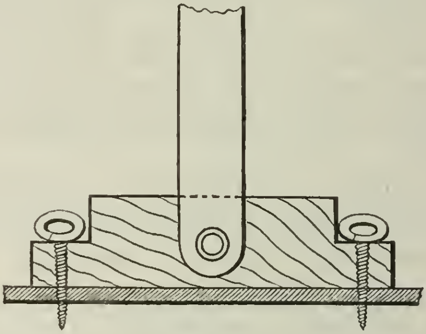


Fig. 5.

When the floor is of such a nature as not to permit of screwing down a base piece, I have used a heavy square-sided balk of wood, weighted down with castings. (Fig. 7.)

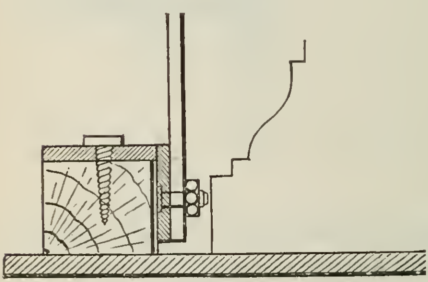


Fig. 6.

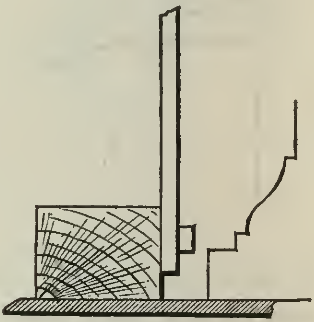


Fig. 7.

Wall attachments and horizontal pendulums are not at all to be recommended, as they are very much in the way, and the point of cord attachment on the pendulum is necessarily far out of the line of

the indicator. But they are on rare occasions necessary. It is generally necessary to make a bracket say 18" × 6" × 6" to nail or screw to the wall at the proper height for the crosshead attachment.

When this rig is used, special care must be taken to have the pendulum pivot, the cord attachment and the indicator pulley form a right angle when the crosshead is at mid-stroke; and when the slotted lever is used, to have the pendulum center exactly abreast of the crosshead attachment, when the latter is at mid-stroke.

If these precautions are not taken, the cards will be false; making cut off appear too early on one end, and too late on the other, but in different amounts.

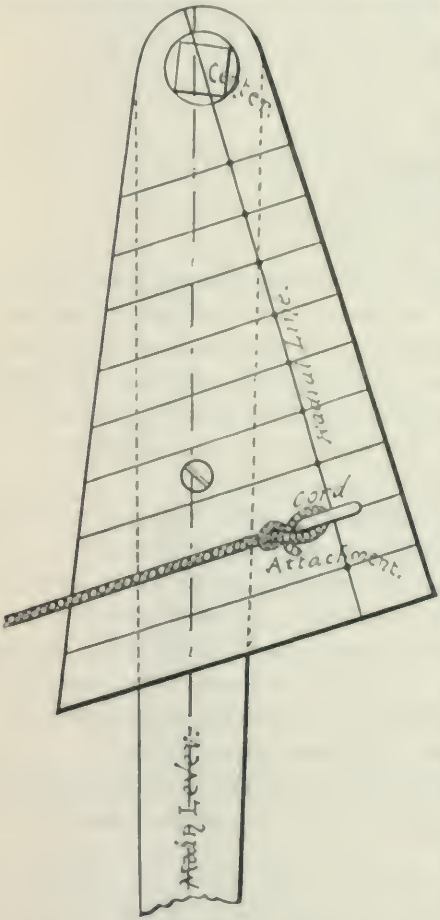


FIG. 8.

I do not know that I can say enough against the use of guide pulleys to bring the cord from the reducing lever to the indicator pulley.

There are very few cases where guide pulleys are at all called for. Perhaps, where overhead piping interferes, they may occasionally be necessary; but seldom elsewhere. They are troublesome to affix, are seldom stiff, and the cord is apt to ride them when slack, and get jammed in between the wheel and its frame, and break when hauled on. I have had to stop an engine that was driving two mills, in order to climb up on it and unhitch or replace the cords from this cause.

Unless there is something in the direct line between the cord attachment and the indicator pulley, guide pulleys are not necessary; as in order to get correct motion it is only essential to see

that when the crosshead is at midstroke, the cord attachment forms a right angle with the pendulum centre and the indicator pulley.

A good way to insure that the pendulum centre, the cord attachment and the indicator pulley form a right angle when the crosshead is at midstroke, is to have a separate arm in the shape of a right angled triangle, having scribed along near one leg a line containing the pendulum centre and cord attachment and having a number of parallel lines drawn at right angles thereto. This arm is pivoted on the same bolt which carries the main lever, and is adjusted to such an angle that the cord going to the indicator pulley will lie at right angles to this radial line. A light screw holds it in this position. (Fig. 8.)

DOCTORING INDICATOR CARDS.

By Robert Grimshaw.

I found out some years ago, to my loss and disgust, that a card is not by any means *prima facie* evidence of good or bad engine performance; and I shall here enumerate for the benefit of my readers a few of the tricks which I know to be practised; trusting confidently that this *exposé* will prevent much more tricking than it causes.

One of the most common and literally transparent tricks is presenting tracings instead of the original card.

Another is omitting the atmospheric and boiler pressure lines and drawing them in afterwards where best desired. This trick is also modified by drawing one of these in properly while the paper is on the barrel, and then shoving the paper down, if the atmospheric line is drawn, or up if it is the boiler pressure line. Thickening all the lines so as to bring the diagram nearer the horizontal lines named, is practiced; as is "taking the atmosphere" with steam connection not quite shut off. The latter is very often done unwittingly.

Taking cards only from the end that has the highest initial pressure or the freest exhaust, or the least clearance, is not unusual with one or two engine-builders.

About the best opportunity for deception is offered by the reducing rig.

We will suppose that the valves as made and set, cut off too late at the back end. The instrument is applied to the back end, and the cut-off point in the diagram set back from its proper place, if a reducing

wheel is used, by leading the cord at an angle from the true parallel with the piston rod, which it should occupy at all positions of the crosshead. If a lever rig is used, the cord angle is made such as to give, for the first quarter or eighth of the outstroke, too little motion of the paper drum; and for the expansion period too much.

THE SUN-EARTH BALANCE.

By Pliny Earle Chase, LL.D.

The following is the shortest method which has ever been published for estimating the sun's distance. I believe that it is also the most accurate method, for the following reasons.

1. If the hypothesis of an all-pervading luminiferous æther is true, all its cyclical movements must be rhythmic, or harmonic, the various forms of rhythm being governed by various centres of oscillation.

2. The simplest kinds of oscillatory motion, in cosmical bodies, are linear and spherical.

3. Laplace showed, in discussing the motions of Jupiter's satellites, that whenever there are tendencies to simple numerical relations, in planetary arrangements, all the forces of the system combine to make those tendencies exact.

4. The sun is the principal centre of attraction, and the earth is the principal centre of condensation in the solar system.

5. The earth is also a centre of linear oscillation for a point in the orbit of Mars, a centre of rotary inertia for a superficial film of condensation or of luminous undulation in the same orbit, and a centre of rotary inertia for an æthereal sphere which has its limit in the asteroidal belt.

The action and reaction of æthereal waves, between these two important centres, have produced an amount of gravitation, at the earth's surface, which is sufficient to give a circular orbital velocity of $\sqrt{gr} = 4{\cdot}9073$ miles per second. The linear oscillation of the earth around the sun, combined with the superficial resistance at the outer limit of the belt of greatest condensation, multiplies the energy by $\frac{3}{2}$, and the rotary æthereal oscillation multiplies it by $\frac{5}{2}$. Consequently, the earth's velocity of revolution, which measures the projection of *vis viva* against uniform resistance, is $\frac{3}{2} \times \frac{5}{2} \times 4{\cdot}9073 = 18{\cdot}4024$ miles

per second. There are 31,558,149 seconds in a year; therefore the sun's distance is $18{\cdot}4024 \times 31{,}558{,}149 \div 2\pi = 92{,}428{,}300$ miles.

The sun can be weighed by its musical rhythm, with a corresponding facility. Orbital velocities vary inversely as the square root of the distance from the centre of gravity. Any two attracting masses bear the same ratio to each other as the distances at which they would communicate equal orbital velocities, to particles which revolve about the centre of gravity of the attracting bodies. Hence we have

$$\overset{\text{Earth's rad. vec.}}{92428300} \times (\tfrac{5}{2} \times \tfrac{3}{2})^2 : \overset{\text{Earth's rad.}}{3962.8} :: 327994 : 1.$$

In other words, the sun weighs 327994 times as much as the earth.

There are many other harmonic tendencies, which are introduced by the masses and distances of other planets, as well as by the correlations of electrical, chemical, and other forces, which may slightly modify these estimates. There is, however, no likelihood that the adjustments of universal equilibrium would make a secular variation of $\frac{1}{2}$ per cent. in the earth's mean distance from the sun, and there has never yet been any astronomical estimate of that distance which has so small a probability of error as the one here given.

Injurious Effects of Illuminating Gas.—Dr. Arnozan recounts many accidents, which have fallen under his observation, among persons who have used gas for cooking. These accidents, which are almost always of a medical character, are especially frequent when the gas is burned in portable furnaces, which are not provided with a suitable chimney for carrying off the products of combustion, or when the gas is allowed to remain in rubber tubes. The latter risk may be mostly avoided by shutting the gas off from the tubes whenever the apparatus is not in use; but even then the rubber wears away so rapidly as to require frequent replacement. Whenever gas is used for cooking it should always burn with a blue flame, as in the Bunsen burner, on account of neatness, economy and health. Unfortunately the combustion of the gas is usually very incomplete, on account of the deterioration, or the bad arrangement, of the apparatus. Generally, also, kitchens are badly ventilated. Some accidents are reported from burns occasioned by the explosion of a detonating mixture at the moment when the gas is turned on.—*Génie Civil.; Les Mondes*, Feb. 2, 1884.

STANDARDS OF LENGTH AND THEIR SUBDIVISION.

By GEORGE M. BOND, Hartford, Conn.

[A lecture delivered before the FRANKLIN INSTITUTE February 21, 1884.]

(Concluded from page 295.)

After having thus briefly considered the subject of the "evolution" of a standard, and the conditions under which it must continue in order to be worthy of being called a standard, we will now attempt to show some of the methods adopted for comparing these yard or meter bars, and explain some of the principles upon which the accuracy of the comparison depends.

We have already partly described the way in which the end meter is compared or transferred to a line measure by the reflection of a fine point of platinum, without actually touching the ends of the standard bar. We may now notice how two standard end measure bars may be compared, using a method by which the differences, if any, are greatly magnified, and are thus very readily determined.

A most ingenious application of the laws of the reflection of light was made by Joseph Saxton for comparison of end-measure bars, and for which, in recognition of its value to science, he was, in 1837, awarded the John Scott Legacy Medal, his invention being the Reflecting Comparator. It depends upon the magnified distance of the path of a reflected ray of light, caused by the rotation of a mirror placed vertically, and delicately pivoted, the spindle of the mirror being connected with a sliding bar by a fine watch fusee chain wound around the barrel of the mirror spindle. At the end of the sliding bar, to which this chain is attached, contact is made with the end of the standard to be compared, the other end of the standard being firmly abutted against an immovable "stop."

By first placing the standard bar in position, care being taken to have the bar supported, as you will remember, at the "neutral points," and exactly in line, so that the centers of the opposite ends of the standard are against the contact surfaces of both the stationary and the sliding stops—and which, by the way, is one of the most difficult features of the experiment—a ray of light is brought to bear upon the mirror, and the reflection of a circular scale is observed through a small telescope, mounted just above this divided arc. This circular scale may be placed at any convenient distance from the mirror, say 15 or 20 feet.

It is evident that a very slight motion of the sliding bar, *G*, in the figure shown upon the screen, (Fig. 1), will cause a ray of light, reflected from the mirror, *M*, to which its motion is imparted through the small chain and drum, to move with a much greater velocity at the distance of the large circular scale, *R S*, and, as the angle of incidence is equal to the angle of reflection, a motion of the mirror through an arc of 5 degrees would cause a motion of the reflected ray of 10 degrees, as we may readily understand by taking the geometrical proof in illustration.

A polished surface is placed so that the light strikes it "squarely,"

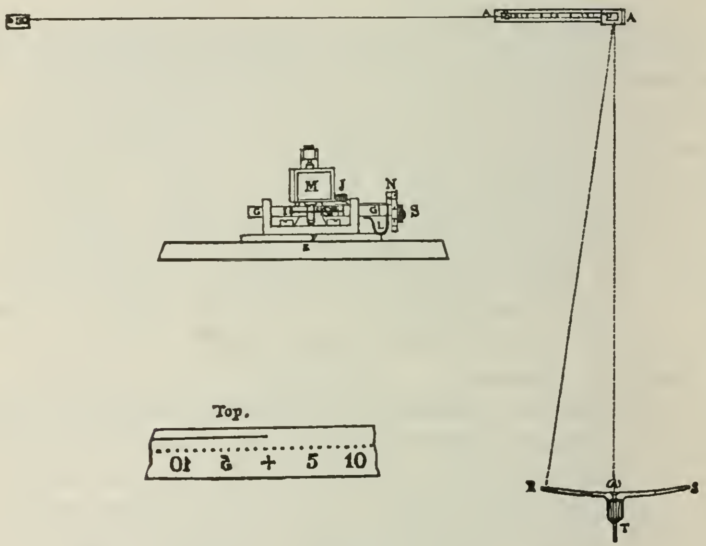


FIG. 1.

or, in other words, at no angle whatever; it will evidently be reflected directly back to its source. Now, suppose it is rotated into such a position as indicated in the accompanying figure, (Fig. 1*a*), which is just 45 degrees as compared with its original position, the light still coming from the same direction; it now strikes it at an angle of 45 degrees, and as light is always reflected at the same angle as that at which it strikes a polished surface, its new path will be again 45 degrees from the plane of the mirror; but, as you will see, it is twice 45 degrees with respect to its incident path, and is thus reflected at an angle of 90 degrees.

We can readily see how extremely delicate or sensitive to the slightest change of position this reflected ray becomes. As light may be said to have no weight, and consequently no momentum or inertia, it will quickly and certainly indicate the slightest change in length of a standard end measure bar.

By calculating the length of the relative "lever arms" we can

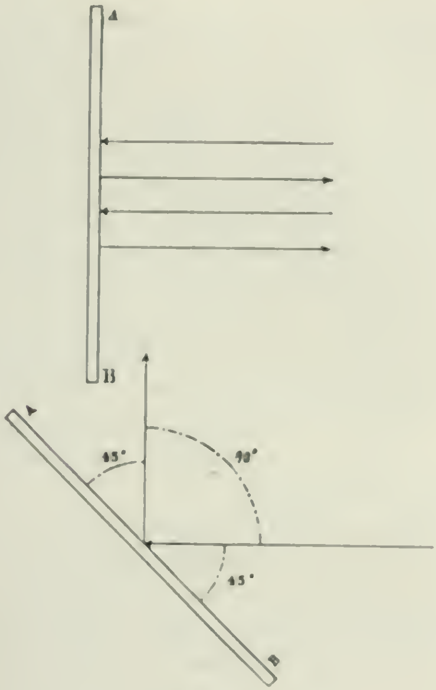


FIG. 1*a*.

easily determine the magnifying capacity of such an instrument of precision. For instance, supposing the drum on the spindle to which the rotating mirror is attached is one-quarter of an inch in diameter, and that the length of the radius of the large circular scale is 20 feet, we have, using the double angle in this relation, the distance moved by the sliding bar touching the standard, as compared with the arc passed over by the reflected ray at the distance of 20 feet from the mirror, and reducing to the same unit as $\frac{1}{8} \times \frac{1}{12} \times \frac{1}{40} = \frac{1}{3840}$ is to 1, or as 1 is to 3840, hence a motion, or variation of one-thousandth of an inch at the point of contact would be 3·84 inches at the scale.

By placing a metallic bar in a closed tube, the ends merely projecting through this tube, and filling the tube with ice water, and then with water of a known higher temperature, and comparing the lengths of the same bar under these varying conditions, the amount of expansion for each degree can be determined; this will give us what is called the coefficient of expansion, to which reference has already been made.

The comparator in use by the United States Coast Survey at Washington, designated as the Saxton Yard Dividing Comparator, is one designed by Mr. Saxton while in charge of the construction of standard balances, weights, and measures of length, to be presented to the different States, to insure uniformity throughout the country.

A short description of this comparator may be quoted from a paper read by Professor W. A. Rogers before the American Academy of Arts and Sciences, April 14, 1880, "On the Present State of the Question of Standards of Length," and from which, also, much that is of interest in regard to our subject matter for this evening has been obtained. Any one wishing to pursue the subject further, the paper entire, and the references contained at the end will be of very great assistance.

"The Saxton Comparator consists of a brass bed-plate, having V-shaped ways running the entire length. A slide carrying a microscope slides freely over these ways.

"A series of brass posts form a part of this bed, through which pass steel screws, having conical ends, which have been tempered and polished. There are stops for the yard and for its subdivision into feet, and of one foot into inches. There are also stops for the meter and for its subdivision into decimeters, and of one decimeter into centimeters. * * * The end stops for the yard and for the meter were, many years ago, set to correspond with "Bronze No. 11," at 58° nearly for the yard, and with the iron meter at 68° nearly. * * * The standards which have been distributed since 1856 have been transferred from these distances at the temperatures at which they are standard.

"The yard in actual use at the Bureau of Weights and Measures, therefore, may be defined to be the distance between two steel stops attached to the bed of the Saxton Comparator which corresponds to the length of Bronze No. 11, at 58° nearly, and the meter may be defined to be the distance between two steel stops of the Saxton Comparator which corresponds to the length of the iron meter corrected for the

difference between its length at 32° and at 68°, nearly. Recent comparisons indicate that these temperatures should be diminished, by a trifling amount, for the present distances between the stops both for the yard and for the meter."

Engravings representing the Saxton Yard Dividing Comparator and also the Saxton Reflecting Comparator here shown, were obtained through the kindness of Prof. J. E. Hilgard, Chief U. S. Coast Survey, by whom every facility was afforded me for examining the methods of comparison. The courtesy of Mr. Blair, assistant in charge, has aided me greatly in thus being able to illustrate the instruments now in use at the office of the Coast Survey.

Another form of a comparator, which has proved to be successful in the use of the means "for the end sought," in the comparison and investigation of standards of length, is that known as the Rogers-Bond Universal Comparator, which was constructed from plans proposed by Prof. Rogers by the Pratt & Whitney Company, of Hartford, Conn., for their use in practically establishing standard gauge dimensions. A duplicate comparator of this form was also made by them for Prof. Rogers for his professional work at Cambridge, and for the transfers and comparisons of standards used by the Pratt & Whitney Company as the basis of these standard sizes.

The comparator at Cambridge is also used by Prof. Rogers in determining the coefficients of expansion of the various materials used in the construction of standard yard and meter bars, and also for obtaining the relation between the length of the Imperial Yard and the "Mètre des Archives." The solution of this latter interesting and difficult problem is fully given in a Memoir by Prof. Rogers, presented May 9th, 1883, before the American Academy of Arts and Sciences, entitled "Studies in Metrology," and to which reference may be had.

The special features of the Universal Comparator are, as its name implies, the variety of the methods employed and the range of work that can be done in comparing standards; each independent method, when carefully carried out, producing similar results which serve to check or prove the comparisons. It includes a method for investigating the subdivisions of the standard by comparing each part of the total length with a constant or invariable quantity or distance.

By the aid of the diagram of the plan and elevation of this form of comparator, the aim being to exhibit *principles* rather than a picture

of the instrument, we may be able to describe in a few words the main features of its construction. (Fig. 2).

A heavy cast iron base A, is mounted upon stone capped brick piers, giving a permanent foundation to the apparatus. Upon this base, and reaching from end to end, are two heavy steel tubes, B and C, three inches in diameter, ground perfectly straight, and being "true" when placed in the centres of a lathe, the object being to get a straight line motion of the microscope plate D, which slides freely on these true cylinders.

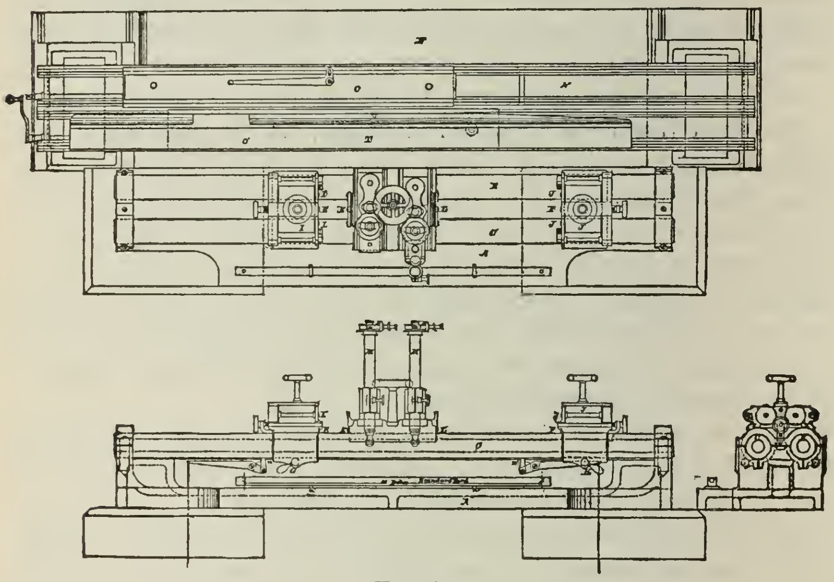


Fig. 2.

Flexure of these cylindrical guides is provided for, by lever supports at the neutral points n and n^1. Fitted closely to these guides, and outside of the range of motion of the microscope plate D are two stops, E and F, one at each end, as shown in the figure. These stops are arranged to be adjusted at any desired position along the guides, and are securely held by clamping on the under side by the handles G and H.

These stops are each provided with a pair of electro-magnets, I and J, the poles of which do not come in contact with the armature seen at either end of the microscope plate. Contact is made at K and L, which are hardened steel surfaces, tempered and polished, and placed as nearly as possible in the centre of the plate and of the stops.

The magnets are intended to overcome the unequal pressure due to ordinary contact, a rack and pinion being used to move the plate. The magnets are used to *lock* the microscope plate at each end of its traverse between the stops. The use made of this sliding microscope plate and the stops we shall see presently.

Beyond the main base just described, and supported also on brick piers, is an auxiliary cast iron frame *N*, which is provided with lateral and vertical motion within limits of zero and 8 and 10 inches, respectively, for rough or approximate adjustment, and upon the top of this frame are two carriages, O and O^1, which slide from end to end, a distance of about 40 inches. Upon these sliding carriages are placed tables T and T^1, provided with means for minute adjustment, for motion lengthwise, sidewise, and for leveling, thus permitting the adjustment of a standard yard bar quickly, and without the necessity of its being touched with the hands after being placed upon the table until the work of comparison is completed.

Before describing the operations necessary for a series of comparisons, it may be well to explain the peculiar fitness, for purposes of this kind, of the microscopes M and M^1 used in this connection.

The tubes are 12 inches long and 1¼ inches diameter, the eye-piece micrometers m_1 and m_2 were made by Joseph Zentmayer, of this city, whose skill as an optician is too well known to require further proof of their excellence. The objectives were made by the late Mr. R. B. Tolles, of Boston, and are each fitted with his illuminating prism.

In order to use a microscope upon lines ruled on polished surfaces, or on any opaque material, some means for obtaining sufficient light must be employed to see them distinctly, without the use of reflectors, which are often a source of error in standard work.

In no other form of objective does this requirement seem better fulfilled than in that invented and made by Mr. Tolles. The objectives are each fitted with a prism of perfectly clear glass, placed just above the lower lens, and one end of the prism passes through the side of the objective. The inner end of this prism is beveled, (Fig. 3), forming such an angle of the end surface to the axis of the prism, that light is refracted perpendicularly upon the surface of the bar, lines less than $\frac{1}{30000}$ of an inch in width being easily seen and separated with a one-inch objective. It may be said to "carry its own lantern," and with light so thrown, just where it is most needed, the *bottom* of the cut or furrow of a line cut by a diamond edge, as fine as that just

stated ($\frac{1}{300000}$ of an inch), as well as the *edges* of the furrow, can readily be seen.

This method of illumination has proved to be *invaluable* in the work of comparing line measure standards, especially so in the case of bars having the lines ruled on polished gold surfaces at the bottom of wells sunk one-half the depth of the bar, these wells being not over one-half an inch in diameter, as in the case of Bronze 1, and also of the bar now before you.

The first operation in the use of this form of comparator is to level the main base, *A*, then sliding the microscope plate *D*, from end to end of the steel tubular guides, having the microscope adjusted so as to be in focus upon the surface of mercury held in a shallow trough, over which the microscope passes, the curvature due to flexure of the guides

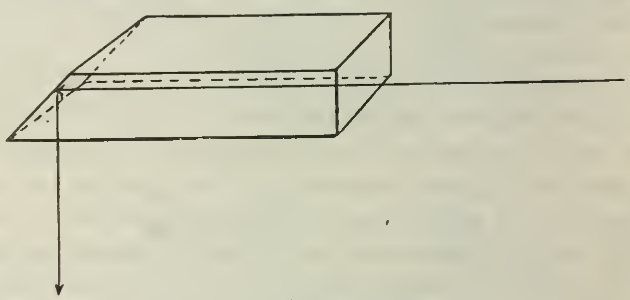


FIG. 3.

is determined, and may be compensated for by counter weights at the neutral points of support, n and n^1.

In order to test this right line path of the microscope plate horizontally, the method of the "stops" is employed, or, another method, which is that of tracing a fine line the entire length of a standard bar upon its upper surface, and reversing the bar, tracing another line very near the first and at an equal distance apart at each end; then if this distance is uniform between the two lines the entire length, it is safe to assume that the path of the plate is a straight line horizontally, and at the middle, the amount of curvature, if any, and also if regular, is readily determined. This method has been used by Professor Rogers with marked success.

The "stop method" is to compare a line measure, or an end measure bar, on each side of the centre line of motion of the microscope plate, using *one* microscope, and comparing this fixed length with the con-

stant quantity before referred to, which is the distance between the stops. Should the path be a curved one, the distance between the defining lines upon the bar will appear greater on one side than on the other in proportion to the amount of curvature existing. The length of the standard being the chords of circles of different radii, but by comparison with the stops, seems really to be different in length at each position, caused by the different distance, through a larger arc passed over by the microscope. By means of the proportion of similar triangles, the lengths of the radii may be very accurately determined.

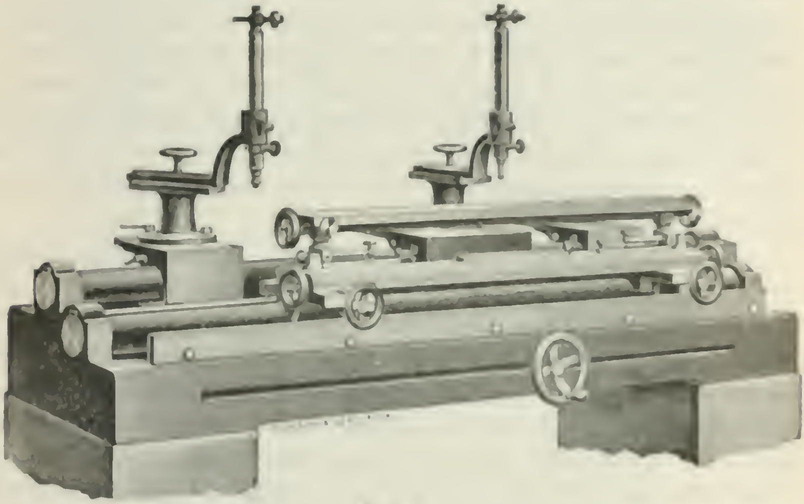


Fig. 4.

By placing different standards on one side of the line of the stops, they may be, by being compared with a constant quantity, compared also with each other.

Another method for comparing two or more standards, is to place two microscopes one on each of two microscope plates upon the guides, at a distance determined by the length of one of the standards, and by replacing this one by a second, the coincidence of the lines in the eye-piece micrometer, or their variation, showing their relation. The microscopes may be placed horizontally in this same fixed relation, using the method invented by Lane, and which has been used in the office of the U. S. Coast Survey at Washington.

A modification of this form of comparator, (Fig. 4) made by the Ballou Manufacturing Company, of Hartford, Conn., for Prof. Anthony, of

Cornell University, is here shown. The instrument is mounted upon a single heavy base. Though not having the range of motion of the adjustable support for standard bars shown in front, as is possible with the original comparator, it possesses all of the conveniences for rapid adjustment and accuracy of movement. The right line motion of all moving parts longitudinally, is governed by heavy cylindrical guides, and the same method of the "stops" is used in investigating the subdivisions of a standard bar.

There are five independent methods for comparing standards of length by the use of this form of Comparator, but we will not dwell longer upon this part of the subject, but pass to the subdivision of standards of length, which is effected by the use of this same process—the microscope plate sliding between fixed stops—and which serves to beautifully illustrate one of the fundamental principles of science, that "things equal to the same thing are equal to each other," or, that the *relation* of different lengths each to a constant distance, establishes their relation to each other.

This is accomplished in the following way: A yard, for instance, is to be subdivided into 3 equal parts, or into 3 separate feet. We divide the whole length by trial into 3 parts, then by setting the stops so that the microscope plate may move very nearly the distance represented by the first one of the 3 parts, by readings of the eye-piece micrometer carefully taken at each end of the path of motion of the microscope, using the finely ruled lines by which these 3 parts are defined, we obtain the length of this subdivision as compared with our constant quantity; then by sliding or moving the bar along under the microscope until the second part is in place, the same operation is again performed, and so for the third, thus determining the relation for each with this arbitrary or temporary standard; then by adding the differences between these separate parts and the constant length, and taking the mean or average of these differences, from which we subtract each difference, gives us the correction to be applied to each part in order that it shall be *exactly* one-third the total length, or, as in case of a yard bar, giving us exactly 12 inches or a standard foot. The foot may then be subdivided in the same manner into 12 equal parts, establishing a standard inch, and further to eighths, sixteenths, thirty-seconds, hundredths, or thousandths of an inch.

To illustrate this method, and to make plain the reason why these corrections so obtained are used, we can suppose a case of simply dividing a rod or a string in two parts. Now we know that for what-

ever amount one part is longer than the other, one half of this amount belongs to the shorter to make it exactly one-half the whole length of the rod or string; hence we have one-half the sum of the difference, and subtracting each difference from this half sum, would in one case, give us a *minus* correction for the longer part, and a *plus* correction to be applied to the shorter.

A series of readings or "observations" using the microscope with the eye-piece micrometer, and having the subdivision of a standard yard into three equal parts, to determine, would be after this form:

First Foot.		*Second Foot.*	
L.	R.	L.	R.
3·68·5	3·98·2	3·57·4	3·87·3
3·68·7	3·97·8	3·57·5	3·87·7
3·68·3	3·98·5	3·57·9	3·86·9
Mean 3·68·5	Mean 3·98·2	Mean 3·57·6	Mean 3·87·3
	R — L = + 29·7		R — L = + 29·7

Third Foot.		*Correction.*	Σ
L.	R.		
3·61·3	3·97·0	+ 29·7 + 2·1	
3·62·0	3·97·8	+ 29·7 + 2·1	+ 4·2
3·61·2	3·97·7	+ 36·0 — 4·2	± 0·0
		3)95·4	
Mean 3·61·5	Mean 3·97·5		
	R — L = + 36·0	Mean 31·8	

The column under "L" being readings taken at the left or initial end of each foot, and "R," readings taken at the right, "R — L" being the difference between the readings taken at each end of this subdivision of the whole length.

The column under "correction" shows the amount in divisions of the micrometer needed to make each foot exactly one-third the yard. Under "Σ" these corrections are added as a check upon the accuracy of the work in case of a long column of corrections, as when the foot is subdivided into inches, or an inch into 16ths or 32nds.

We have thus traced, briefly, the development of the standards of length from some of their rudest units to that of the present British Imperial Yard and its copies, and the metre, and shown how the yard has in one way at least, been subdivided within a limit of about one hundred thousandth of an inch, it remains now to show in what way these accurate subdivisions may be successfully applied to every day use for work requiring such nicety, and in our next lecture it is hoped that our efforts may not prove unsuccessful.

Hartford, Conn., January 11, 1884.

STANDARDS OF LENGTH AS APPLIED TO GAUGE DIMENSIONS.

By GEORGE M. BOND.

[A lecture delivered before the FRANKLIN INSTITUTE, February 29, 1884.]

In our lecture of last week we attempted to show in what way Standards of Length may be constructed, and how these standards so constructed may be subdivided within very close limits of error. We will now attempt to show in what way these subdivisions may be applied to the requirements of modern shop practice, and how the gauges or implements used in work requiring interchangeability of parts are made so as to insure this accuracy.

Manufactured articles have been compared by Sir John Herschell to atoms, on account of their uniformity. The uniformity of manufactured articles may be traced to very different motives on the part of the manufacturer. In certain cases it is less troublesome as well as less expensive to make a great many articles exactly alike, than to adapt each to its special requirements. Thus, shoes and the uniforms for soldiers are made in large numbers, without any design of adaptation to the requirements of any one man. In another class of work the uniformity is intentional and is designed to make the manufactured articles more valuable owing to this uniformity. Thus, for instance, bolts and nuts of any particular size, if alike or interchangeable, may be replaced when worn out or lost, saving an immense amount of trouble, and especially valuable time, in cases of repairs where the stoppage of machinery or the delay of a train of cars would be a matter of serious loss, not only of time but also of dollars and cents.

In the third class, not a part only, but the whole of the value of the object arises from its exact conformity to a given standard. Weights and measures belong to this class, and the existence of well-adjusted standards of weight and measure in any country furnishes the evidence of the existence of a system of law that regulates the business of the people, enjoining in all measures a conformity to the national standard.

There are thus three kinds of usefulness in manufactured articles: cheapness, serviceableness, and quantitative accuracy. Which of these was referred to by Sir John Herschel, we cannot say. It is as likely the last as the first, though it would seem more probable that he meant to assert that a number of exactly similar things cannot be, each of

them, eternal and self-existent, and must therefore have been made. Hence he used the phrase "manufactured articles" to suggest the idea of their being made in great numbers (*Encycl. Brit.*, 9th edition, vol. 3, p. 49).

Adam Smith, the founder in England, of the science of political economy, in his most important work, "The Inquiry into the Nature and Cause of the Wealth of Nations," referred particularly to the benefits derived from a systematic division of labor. He showed by apt illustrations the wonderful results to be attained by this now well-known principle, both as regards the quality and the quantity of the product.

During the score of years from 1765 to 1785, when Adam Smith was working out his memorable treatise just referred to, the inventions which have given us the steam engine and the loom were being perfected. While Adam Smith was lecturing in Glasgow, from the chair of moral philosophy, James Watt was selling mathematical instruments in an obscure shop within the precincts of the same university, and was working out *his* inquiry into the practical methods of applying steam.

In a paper read before the Institution of Mechanical Engineers, at Birmingham, Mr. Edward A. Cooper states that in a letter written to a friend, Watt thought he had attained remarkable mechanical accuracy when a cylinder he bored was so true that he could not get half-a crown between the piston and the cylinder, anywhere!

We must not be surprised at this remark when we consider the materials he used in making his models, and the probable state of the art of making machinery interchangeable at the time he lived. He used tin cylinders, and soldered the joints in many instances. Often he found it gave better results to *hammer* them rather than bore them. A block tin cylinder 18 inches in diameter, ¼ inch thick, when bored was found to be ⅜ of an inch out of truth. He speaks of hammering it with a mallet outside, using a round piece of wood to correct this defect.

Eli Whitney was the first to develop the principle of quantitative accuracy by the use of the system of interchangeable parts in the manufacture of arms for the United States Government, early in the present century. As an evidence of the value of this system, in the year 1822, Mr. Calhoun, then Secretary of War of the United States, admitted to Mr. Whitney that the Government was saving $25,000 per year at the

two public armories alone, by the use of his improvements. This admission, the figures being probably far below the true facts of the case, serves to show that Mr. Whitney deserved well of his country in this department of her service. Mr. Whitney was noted for his exactness, his motto being, that "there is nothing worth the doing that is not worth doing well" (*Am. Journal of Sciences and Arts*, vol. 21, Jan., 1832).

In a paper read by Mr. Chanute before the American Society of Civil Engineers, at a meeting held in Washington, June 21, 1882, on "Uniformity in Railway Rolling Stock," he stated that the average cost of repairs in the shops of the New York, Lake Erie and Western Railroad, for the five years prior to 1875, was 9·17 cents per mile run by locomotives, while for the past five years it was only 4·33 cents. This represents a saving of about $675,000 a year. This was after the system had been adopted by the railroad company of making parts of locomotives in duplicate, using gauges and templates for this purpose. Had the rate of cost of 1871 prevailed in 1881, the expenses of locomotive maintenance would have been $790,492 greater than they were. The conclusion must not be formed, however, that all the above savings, or even a major part of them, have resulted alone from the system above mentioned. Much of the economy is doubtless due to other reforms introduced by the management of the road about the same time; but a considerable part is certainly due to the adoption of rigid standards and of interchangeable parts. Moreover, a very considerable number of the old engines still remain with all their imperfections, so that further benefits may be expected to result from the system as it becomes extended in the future.

In the system upon which the gauges produced by the Pratt and Whitney Company are based, the sizes are all constructed from accurate subdivisions of the British yard, made so carefully that any subdivision of a foot, taking any sizes from a quarter of an inch to four inches, varying by sixteenths, the sum or combination of these sizes taken at random and in numbers, or in sufficient lengths to constitute a foot, will be found to produce in the total sum, exactly the same result.

When we consider that in the experiment just mentioned, the variation of only one-thirty thousandth of an inch in each, if all one way, either plus or minus, would amount to an error in some cases of over half a thousandth of an inch, and particularly in the case of one combination where

fifteen or sixteen sizes were added, it will be seen that the error would be very perceptible in the test which they would thus undergo.

This severe practical test was applied by the Committee on Gauges, of the Society of Mechanical Engineers, in their investigation of this system of making standard gauges, these end measure pieces being found to be within the limit of accuracy necessary to fulfill this condition.*

In the production of these end measures, it is necessary that the end surfaces be perfectly parallel. This is a matter which is a simple operation as done by the Pratt and Whitney Company. Two sides of an end measure standard, such as the one we have now before us (Fig. 1), are made as nearly perfect planes as is possible, and at right angles to each other. The ends are then made perpendicular to these two surfaces, by means of a simple fixture which holds the end measure vertically and clamped in the angle of a movable block of cast iron which slides

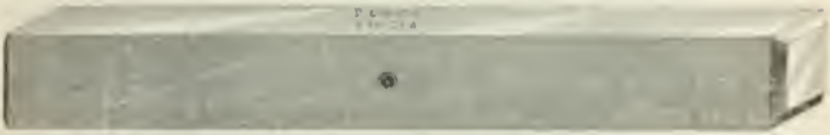


FIG. 1.

freely over the plane surface of another block also made of cast iron. In the centre of this latter block is a copper matrix having diamond dust or washed emery in its upper surface. The end measure is passed rapidly over this surface, and being held perpendicularly, its highest points are ground away, and eventually this surface becomes a polished plane. The bar is reversed and the same conditions are applied to the other end; both ends being perpendicular to the same planes, are consequently parallel to each other.

These parallel surfaces being true planes, are, when brought together, capable of sustaining the weight of either one or the other, or in the case of the two which we have before us they may be held horizontally and still not separate. In a lecture at the Royal Institution, June 4th, 1875, Dr. Tyndall states that experiments by Robert Boyle, with plane surfaces placed in contact, show this clinging tendency even in a vacuum; and that with the surface plates he used, made by Whitworth,

* See Trans. Am. Society Mechanical Engineers, 1882, Vol. iv, report of Committee on Gauges, page 26.

the force necessary to pull them apart was thirty times greater than that due to gravity, showing a mutual attraction or actual cohesion of the two surfaces. This is evidently the case, for we know that if the particles or atoms of a piece of steel are closely enough associated, they form a solid mass. By making their condition, artificially, as nearly like this as possible, the atoms are brought comparatively near each other, and more or less of this cohesive force results.

Of course, in the present case we have, apparently, the weight of the atmosphere to produce this result, but if we consider how small the surface is on which this weight is acting, we must admit that part of this clinging tendency must result from a cohesive force, as in the case before us the surfaces of these end measure pieces are less than a quarter of an inch square, and the weight of air, if there was a perfect vacuum between the two surfaces, would be scarcely enough to sustain this weight, were the surfaces perfect planes.

Perhaps the most marked example of interchangeable work resulting from a standard gauge system is that shown in the thread gauges which represent the Sellers or Franklin Institute thread. This form, proposed by Mr. William Sellers, on account of being adopted by the Government has been called the United States standard thread. In order to produce these standard gauges and to be able to guarantee them as being standard, it was necssary first to establish a standard inch. This standard inch must be one thirty-sixth part of the British Imperial yard, no more, no less. Then having obtained this standard inch, the subdivisions of it were to be obtained. So much for the size. Then in order to produce sixty degrees for the angle of the thread, it was necessary to establish this in a practical way, in order to furnish a gauge by which tools could be made that would insure absolute practical accuracy. This master triangle, designed by Mr. J. W. Heyer, furnishes the means of originating a triangle which shall be equi-angular, and consequently possessing angles of sixty degrees.

In order to obtain accurately the width of the flat, which is one-eighth of the pitch, for top and bottom of the United States Standard thread, it was necessary to establish a model triangle as a starting point, in connection with this master triangle. This model was, when finished, two inches long on each side.

The method used for obtaining a triangle having sides known to be exactly two inches long, without the necessity of their being actually measured, is as follows:

An eight-inch master triangle was so constructed that its center was definitely located by making it of parallel pieces of steel, accurately scraped, and fitted together. Within this triangle, its inner sides tangent to the circumference, was fitted a cylindrical plug or centre. This plug having been turned upon a true mandrel, the condition of the hole passing through it exactly in the centre, naturally took care of itself. A second cylindrical plug, hardened and ground, was next fitted to the centre plug. This hardened cylinder was ground to size exactly equal to the diameter of a circle which should, theoretically, be tangent to an equilateral triangle, whose sides are two inches long. Its diameter is $\frac{2}{3}\sqrt{3}$ or 1·1547 inches.

By holding securely a triangular piece of hardened steel upon the stud passing through the center plug, and having its faces or sides reversed in position as regards the sides of the large triangle, the sides are ground parallel to the sides of the master triangle, and also ground until a sharp edged corrected square, held against the side of the large triangle, determines the tangency of the sides to the inscribed circle 1·1547 inches in diameter.

As the large triangle is carefully tested for equality of angles, this inscribed circle furnishes the remaining data for producing a triangle whose sides are known to be two inches long, without their being measured.

In fact it would be impossible to measure them in any other known way within the limit this method makes entirely practicable, and which at the same time "fortifies" each step in the process by employing fundamental principles, and keeping the limit of error within what is claimed, which is $\frac{1}{10000}$ of and inch. Imagine anyone measuring the sides of a two inch triangle by contact with the almost infinitely sharp edges where the sides do meet; I venture to say no two readings would agree, and it is pretty safe to assume that each succeeding measurement would become less and less, as these fine edges were destroyed.

In the method described, using the inscribed circle, it is not necessary to have any edge whatever, as we may feel certain that the sides *would* be two inches if prolonged to meet each other.

For the purpose intended, it does not matter if these edges are blunt or even truncated slightly, as it is the known *position*, and not the actual length of the sides that is necessary.

In order to have the flat of the thread correct for such a pitch, in this case taking two inches as the base, the flat of which would be one

quarter of an inch or one-eighth of two inches, the method adopted is as follows:

The altitude of the frustum of this triangle was obtained after having removed the smaller triangle at the top, the sides of which are one quarter of an inch, by subtracting the altitude of this small triangle from the total altitude of the equi-angular two inch model, which gave the distance from the base to the top of this truncated triangle. By having this measured exactly, and the top and bottom planes parallel to each other, this distance came naturally, and evidently must be one-quarter of an inch without actually being measured. The actual measurement of this quarter inch flat would necessarily be very difficult, because we are dealing with the edges formed by obtuse angles, and the accuracy would certainly not be within the limit which would be required. After this triangle was established, a micrometer was made, which we have before us, in which the model two-inch triangle is used to determine the extreme limit through which the micrometer jaw shall move; establishing a "zero," if it may be so-called, for a starting point, the jaw of the caliper moving towards the smallest possible flat that could be measured, or that would be required for the finest pitches. This micrometer is, as its name implies, a divided circle and a screw, measuring very small advances of the jaw. In order to verify these subdivisions, lines were ruled by Professor Rogers, four hundred to the inch, with a diamond, upon the polished surface of the center of the bar.

There being 250 divisions graduated upon the index circle, and the pitch of the same being $\frac{1}{40}$ of an inch, each division represents $\frac{1}{10000}$ of an inch.

Each of the lines ruled 400 to the inch upon the sliding bar serves to check or correct the readings of every 25th division of the graduated circle, to provide corrections for possible errors in the screw.

By the use of this micrometer we can accurately measure the flats of the tools which are used to cut the United States standard or Franklin Institute thread of any number of threads per inch. In order to show the adaptation of this form of thread to interchangeable work, and also its extreme simplicity as a basis for an interchangeable system of gauges, we have before us (Fig. 2) a drawing showing how, should this thread be even larger in diameter on the outside, but with the diameter correct in the angle of the thread, the variation of this outside diameter from that of a standard cylindrical size has no effect upon the fit

of the nut which may be screwed upon the standard or upon a bolt representing this standard size. The only difference which we would notice is that the top of the thread would be narrower, and consequently the top would be higher, in the space cut away by the tap. Hence, taps that are made for tapping nuts of the United States standard thread, if made exactly right in the angle of the thread, that is, having the angle sixty degrees, and the diameter measured in this angle of the thread, correct, the outside diameter has no effect, within certain limits, to change its size, merely cutting away within the nut more metal outside of the limit of one-eighth the pitch. In the case of the bolt which fits this nut, the outside diameter should be kept

FIG. 2.

standard, the space between the bottom of the nut and the top of the thread of the bolt, allowing particles of dirt to lodge, without affecting the fit of the screw. This condition is often applied in the manufacture of taps, and has been found to lengthen the life of the tap in a very marked degree.

In the case of one company I have in mind, and who make small bolts and nuts, the taps they use being about three-sixteenths of an inch in diameter, they were formerly satisfied to have a tap cut fifteen or sixteen thousand nuts before perceptible wear occurred, they have found that in having them made in the way just mentioned, instead of stopping at sixteen thousand, they now cut a hundred and twenty thousand without practical variation in the size of the nut as compared with the standard gauge.

As an instance of the "eternal fitness of things," allow me to quote from Mr. Forney's Report* at the Convention of Master Car Builders, held in this city, in June, 1882:

* Report of the Committee of the Master Car Builders' Association, appointed "to investigate and report on the present construction of screws

"It is worthy of note that a remedy for the evil complained of by master car builders, that nuts made by some firms, or at some shops, would not screw on bolts made at others, at first baffled the ability of the most prominent manufacturers of tools in the country, and to provide an adequate remedy it was necessary to secure the assistance of the highest scientific ability in the country, which was supplied through the co-operation of the Professor of Astronomy of the oldest and most noted institution of learning in the land.

"The man of science turned his attention from the planets, and the measurement of distances counted by millions of miles, to listen to the imprecation, perhaps, of the humble car repairer, lying on his back, and swearing because a $\frac{5}{8}$-inch nut—'a leetle small'—will not screw on a bolt a 'trifle large.'"

In the system so wonderfully developed by Sir Joseph Whitworth for the manufacture of machinery by the use of interchangeable gauges, he obtained the subdivision of the yard by making three foot pieces as nearly alike as was possible, and working these foot pieces down until each was equal to the others, then placing them in his millionth measuring machine; the total length of the three foot pieces was then compared with a standard end measure yard.

These three foot pieces were ground until they were exactly equal to each other, and the three added together equal to the standard yard. The subdivision of the foot into inch pieces was made in the same way. This method necessitated extreme care, and also an enormous amount of time. In the method which has been adopted by the Pratt & Whitney Company, the sizes are not constructed in this way, but ruled lines, which represent the subdivisions of the British yard, are first investigated and found to be either accurate, or their corrections are applied, before a single gauge or any end measure is made. This method of investigation you will remember was described partially in our previous lecture.

One can readily understand what an unsatisfactory way it would be to attempt to subdivide a yard, or even a foot, into end measure pieces varying by sixteenths of an inch, say from a quarter of an inch to four inches, sixty-one in all, which would fulfill the condition of being

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and nuts used in cars; and the amount of accuracy that is desirable to secure, and the best means of maintaining it, in the standard adopted by the Association, in Richmond, Va., June 15, 1871," etc.

Submitted at the annual Convention, in June, 1882.

exact aliquot parts of the standard yard, which they each should represent. We can imagine the difficulties to be overcome by any one attempting this work by the subdivision of a standard foot, using the method adopted by Whitworth in 1834. Without having a line measure to which to refer, this standard foot—providing it was standard at the start—would necessarily be subdivided into two parts, each representing six inches, equal to each other of course, and together equal to the foot. Constant reference would have to be made to the standard foot piece, which would obviously result in more or less wear of the end surfaces. Then the six inches would be halved, and so on until the inch was obtained. Then, in order to prove that the inch was one-twelfth of the foot, it would be necessary to make twelve of these inches, or six inches equal to the six-inch piece, and the sum of all to be equal to twelve inches, or the original foot. We can all of us realize what has occurred to the standard foot in the course of this constant reference to it as the original standard.

Providing, even, that all these subdivisions were carefully made, and that no wear perceptible had occurred to the original standard, we are still not below an inch.

Subdivisions into quarters and sixteenths would still further complicate the matter. When the subdivision was complete, providing the operator's patience and life held out, he would then not be positive that he had even the inch a standard, having by this time worn out his original foot during such a long and tedious process.

Hence a line measure is really the only means of preserving this constant and standard quality for size, and it is this principle which has been the means of producing results, which so far, seem to fulfill all the requirements for an accurate system of interchangeable gauges.

In order to help out the matter, recourse must be had, for further subdivisions, to the use of a screw and a divided micrometer index circle. Just here we introduce the use of what has long been considered one of the impossibilities to be obtained by mechanical skill—a perfect screw. It was this that Whitworth was obliged to depend upon in obtaining his subdivisions by sixteenths. We have before us upon the screen a perspective view of the celebrated Whitworth millionth measuring machine, designed and used by Sir Joseph Whitworth to measure minute differences of inch standards. This machine, as you will see, combines the use of a screw for obtaining slight advances of the measuring faces of the instrument, a divided micrometer circle

and also a worm wheel to still further reduce the value of each division upon this carefully constructed micrometer.

We have now a section view of this machine, showing the method of providing against back lash of the nut and screw, which is secured by a double nut, as shown (Fig. 3) in the drawing before us. You will notice that the machine is very massive, and the accuracy with which it was constructed is designed to indicate with extreme delicacy differences between any two standard inch pieces, so called. Between the movable end of the rectangular bar which advances by means of the screw and nut, and the standard end measure piece, is a small polished piece of steel, having parallel faces, called a "feeling piece." The difference in length of two pieces is detected, it is claimed, by the variation in the reading of the divided wheel, and the uniformity of contact is indicated by means of this feeling piece.

The tightness of an end measure inch only one millionth of an inch

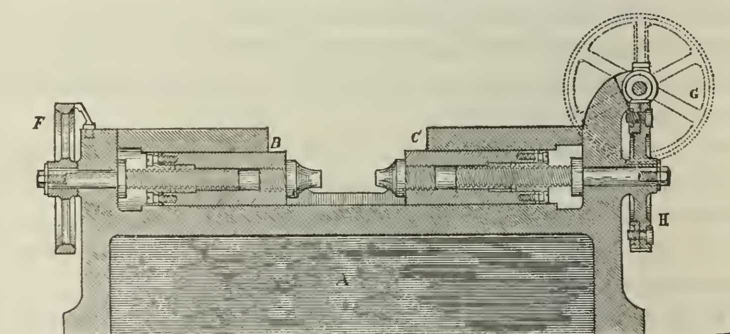

Fig. 3.

longer than one to which the machine had previously been adjusted, will, it is claimed, prevent this feeling piece from dropping when placed between the caliper jaw and the standard.

In order to make gauges for shop use, and to make them in such a shape as to be practical and not readily worn through constant reference, Whitworth proposed a form of cylindrical gauges represented by plugs and rings. These standard plugs he measures in his machine, duplicating his end measure sizes in this more practical form.

In using his measuring machine, he does not claim it to be an instrument for originating sizes, but merely for comparison of minute differences. Hence in order to maintain a constant standard, reference must be had to end measures which are certainly liable to sustain some

slight change from wear or oxidation. In the method used by the Pratt & Whitney Company, and which was proposed originally by Professor Rogers, the system adopted is that of making gauges to correspond to the lines which are accurate subdivisions of the Imperial yard, thus removing this liability to wear.

The gauges are made by referring each separate standard to a line which is ruled upon *hardened steel*, which has a rate of expansion the same as that of the hardened steel gauge with which it is compared. In making any number of gauges of the same size, this method will ensure the last gauge being exactly the same as the first, without reference to each other or to any other perishable standard. This has actually been done in the work so carefully gone through by the company, and it is possible and entirely practical to produce gauges so nearly alike by this means, that a variation between any two,

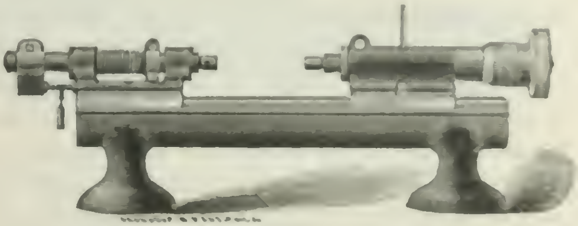

Fig. 4.

of even one forty or one fifty-thousandth of an inch can be discovered. We have found from our own experience that tool makers are very critical. They work closer than they themselves imagine, and in duplicating parts of any machine or any work requiring this exactness, they work often within a fifty-thousandth of an inch without being aware of the fact; so that in making a number of gauges of the same size, it is certainly necessary that they should be made within this limit. Nothing could throw more gloom over the spirits of a manufacturer of guages than the discovery that a tool maker is able to prove that two gauges, both marked alike, are unlike in size.

In the illustration before us (Fig. 4), we have a form of a simple bench micrometer or measuring machine, in which the screw and subdivided index circle form the main features.

In order to obtain practically the same result in duplicating sizes from a standard for ordinary gauge work, an auxiliary set of faces or

caliper jaws are used, and are shown at the extreme end of the instrument. These auxiliary jaws serve to hold a small cylindrical plug, so that in adjusting the machine or caliper to any given size, the pressure between the caliper jaws in which this standard is placed can be determined by the tightness of this small cylindrical plug. By taking the reading on the micrometer and bringing a second gauge in place of the original, the same conditions of pressure upon this second gauge may be readily determined, by noting the behavior of this little "feeling piece," as Whitworth might call it. The variation may then be read in the ordinary way by the subdivisions upon this divided index circle. As an instrument for originating a size, even with a screw of the utmost precision, it could not be expected to be infallible; but to copy or duplicate sizes it has been found to be very serviceable. A variation as minute as one hundred-thousandth of an inch has been shown to be appreciable in a case which has come under my own observation.

In order to make standard gauges within the limit of accuracy necessary for interchangeability, and to fulfill the requirements of modern workshop practice, it may be unqualifiedly stated that *line measure*, adapted for use as a practical reference, is the best standard for this purpose. The strong reason for this statement is that the ever present element of wear from constant use is entirely eliminated.

The standard line measure bar we now have before us, is one which has certainly shown this to be not only a strong reason, but a valid one. The lines which represent aliquot subdivisions of the Imperial yard, were ruled upon a dividing engine constructed by Professor Rogers, the work being done at the factory of the American Watch Company, at Waltham.

The total length, represented by the defining lines, is *exactly* one-ninth of the length of the Imperial Yard, or four inches, having no correction at 62°F. In other words, it is within a limit of $\frac{1}{100,000}$ of an inch. The subdivisions are inches, half inches, quarters, eighths, and sixteenths along one edge, and a band of lines, 2,500 per inch extending two inches from one end. Next is ruled a series of lines representing the bottom diameters or "tap sizes" of all United States standard thread gauges from $\frac{1}{4}$ to 4 inches inclusive.

Along the edge opposite the series of sixteenths, is ruled tenths and twentieths of an inch, covering a space also of two inches. This bar is made of steel, hardened and ground perfectly plane on its upper surface and highly polished. The graduated lines were transferred to

this surface using a *metric* screw, the pitch of this screw being one-half a millimeter. The ruling was done with a diamond. So carefully was the relation between the pitch of this metric screw and the length of the yard determined by Professor Rogers, that upon investigation, using the method of the "stops," mentioned in our previous lecture, the errors were found to be within $\frac{1}{50,000}$ of an inch for the particular subdivision of the Imperial yard which each represents.

When we realize that the transfer of each separate line, except the band of 2,500 per inch, was an actual computed setting of the diamond before the lines were traced, some idea may be obtained of the wonderful precision of the mechanism of the dividing engine, as well as the accuracy of the mathematical calculations involved.

Being hardened steel, the measurements of hardened steel gauges by

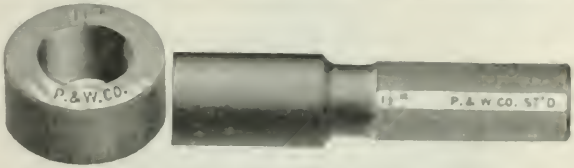

FIG. 5.

being referred to it, becomes entirely practicable at any convenient temperature, providing, of course, that an equal temperature for both standard bar and gauge is maintained. As the lines are less than $\frac{1}{25,000}$ of an inch in width, all comparisons must be made using a microscope.

The practicability of "calipering" under a microscope has long been urged by Professor Rogers as being the *only* exact method of inspecting standard gauges. The result obtained by use of this method, combining as it does, science and practice, has demonstrated beyond any question, the simplicity, as well as the accuracy of the method. To give some idea of its value for the purposes of *originating* standard sizes, an instance in mind may be stated.

A number of cylindrical size gauges, external and internal, a representation of which is shown in (Fig. 5), commonly called plugs and rings, were made. They were finished to agree with the subdivisions upon this little hardened steel line measure standard. Nearly eighteen months afterward, a new lot of the same sizes were made, and upon trial it was shown that any ring of the first lot fitted perfectly any plug of the second. Both lots had been made without reference to any

intermediate standard set of plugs, except to "rough them out," as it is called, within about $\frac{2}{10000}$ of an inch, all finishing after this having been done from data determined by calipering under the microscope.

A good gauge fit is not that the ring shall slide freely over the plug without perceptible "shake," but one such that the ring, when well lubricated with sperm or other *good* oil, shall move easily after having it fairly on the plug, showing no tendency to "grip" the plug while the ring is kept moving. Let the ring, however, stop moving even for a few seconds, and this condition of an apparently easy fit is suddenly changed to a *driving* fit, often causing serious damage to the gauge in separating them. In order to show this condition of perfect fit to best advantage, the temperature, of course, must be the same for both. The surfaces of the plug and ring must be as hard as steel can be made, and polished as carefully as the state of the art will admit. A good way of testing the accuracy of any set or pair of cylindrical gauges in reference to their being aliquot parts of any adopted standard, is to place within a ring which fits a standard plug, two smaller size gauges, tangent to each other, and if their sum is equal to the diameter of the larger single gauge, they will be tangent to the ring also. If exactly right, they will be found to hold together tightly, as the elements of cylinders which are in contact must either occupy the same space or be compressed enough to allow this practical tangency to be made. Care must be taken not to force the second gauge in too far, as this would evidently tend to injure them.

In the gauges before us, which are $2\frac{1}{4}$, $1\frac{1}{4}$ and 1 inch, we may see how nicely this test is met. If we use a gauge which is $\frac{1}{1000}$ of an inch smaller than one inch in diameter, the tangency is incomplete, for this gauge drops through, hardly touching.

A thousandth of an inch, you may say, is almost not worth considering, but here we have a standard plug and ring, the ring fitting perfectly, as you see. We now insert the plug, which is only $\frac{1}{1000}$ of an inch too small; it can be literally thrown on or off, one might even say that it "fairly rattles," the difference seems so great as compared with the fit of the standard.

We have here a $\frac{3}{4}$-inch plug, it is only $\frac{3}{10000}$ of an inch smaller than the standard, the plug and ring representing which we also have. You will notice it is not so loose as was the inch plug $\frac{1}{1000}$ small, but still one-third of this is perceptible, and shows plainly that it does not perfectly fit the ring.

In our experience in the manufacture of standard gauges, even this test is not a delicate nor a satisfactory one. It is not equal to that obtained by the use of a fixed caliper gauge having polished parallel jaws, a specimen gauge of this form we have before us (Fig. 6).

For the purpose of testing the larger sizes, this form of gauge is the best, as the friction between the two surfaces is a variable quantity depending upon the degree of hardness and polish of the fitting surfaces of plug and ring. It is possible, also, that the cohesive force

FIG. 6.

which we have mentioned, may act in this close-fitting relation, explaining why the ring should suddenly be so tightly "gripped."

With a two-inch gauge, a variation of $\frac{1}{20000}$th of an inch is imperceptible, when a ring is used to determine this small difference, while with a caliper made as just described, having polished parallel jaws, this minute difference may be readily detected, if the caliper be first carefully adjusted to a standard two-inch cylindrical gauge.

To convey some idea of the minute variation which may thus be detected, I may state that a fragment of gold leaf, so thin that a mere touch of the fingers caused its total disappearance, on being carefully measured under the microscope, showed that its average thickness was $\frac{1}{30000}$th of an inch.

This same gold leaf would actually float in the air like a spider's web, and yet this extreme "thinness," if it may be so termed, is actually twice the limit of error within which it is possible to duplicate standard plug gauges, referring them to a line measure under the microscope.

The lines ruled upon this standard line measure bar in the space covered by the first two inches, 2,500 per inch, if placed one inch apart, the lines being magnified in proportion, would be represented by furrows or marks one-tenth of an inch wide, and would extend over a length of 416 feet 8 inches, or nearly one-twelfth of a mile.

The measurement of the diameter of drawn wire has long been a matter of confusion, owing to the use of numbers to designate arbitrary sizes which in many cases do not correspond with each other for the same numbers used in different standards or styles of fixed wire gauges. Even wire gauges of the same standard do not agree with each other, due perhaps to wear, if not from actual variation when new. To overcome this serious difficulty, the use of the micrometer, indicating thousandths of an inch for wire and sheet metal measurement, was adopted by the Association of Master-Mechanics, in Convention at Niagara Falls, June, 1882.

Since this date, in England, the Standards Department, Board of Trade, has issued a table of wire gauge sizes which are to be the legal standard on and after March 1st, 1884 (which, by the way, is to-morrow). In the table just mentioned, the numbers are retained, but each number shall represent exactly a certain diameter in thousandths of an inch. The table is also extended to include the metric system by placing opposite each size in thousandths of an inch, its value in millimetres, carried out decimally to tenths of a millimetre.

This table, for instance, begins with No. $\frac{7}{0}$, which is ·500 of an inch in diameter, or 12.7 millimetres. No. 1 is ·300 of an inch, and No. 50, the smallest in the list of sizes, is ·001 of an inch. The range, we notice, is from one-thousandth of an inch to one half of an inch. The variations are irregular, not advancing by equal amounts for each succeeding larger size. This is no doubt due to the effort to retain as nearly as possible a general average of the old wire gauge sizes. In every case, however, the exact size is stated in thousandths of an inch. The feeling in regard to the great lack of a uniformity in wire gauge sizes under the old notched gauge system, may be best expressed by

a remark recently made by the master mechanic of one of our best Eastern railroads.

He said that any one would be as likely to go to a lumber yard and order a plank ten feet long, twelve inches wide, and as "thick as a notch cut in a fence post made by Tom Jones," as to think of ordering sheet metal, specifying that it should be simply "No. 13 wire gauge," as has often been done, not even stating by what gauge it is so called.

The application of standards of length to ordinary work-shop practice has so wide a range that it would be impossible, in the time at our disposal this evening, to attempt an enumeration of the many forms of gauges and templates necessary to secure the three important elements we have already mentioned, cheapness, serviceableness, and quantitative accuracy, even in a single department of work requiring interchangeability of parts, as for instance the manufacture of sewing machines, or the results obtained by the use of standard gauges in the manufacture of firearms.

It must not, however, be understood that all work produced is as perfectly in duplicate as are the gauges to which they are referred.

The guages are the means provided for keeping within bounds in the production of thousands of pieces of the same size or shape, in which oftentimes a certain amount of variation is allowed, both plus and minus.

Standard gauges prevent the gradual slipping away from the original size, and serve to bring back within the limit, variations of size, which would cause endless trouble and no small loss in the final assembling of these intended interchangeable parts.

This accurate fitting is only really necessary in gauge work, for if bearings or other parts of machinery were so closely made they would not move, or if by applying power enough they should be started, the absence of oil and the effect of the cohesion, if we may be allowed to say it, would quickly ruin the surface in contact.

A certain amount of "looseness" must be allowed, and by making the journals and the bearings in which they run, to certain definite sizes for each, the journal as many thousandths or ten thousandths of an inch smaller, as the size or length of bearing may require, referring each to some particular gauge as a standard. This being done, no fear may be entertained that other than a satisfactory fit may be the practicable result.

Before concluding, brief mention should be made of the efforts to

secure uniformity in gauge dimensions for steam and gas pipe thread fittings; a standard for which is now claiming the serious attention of manufacturers and users of pipe and pipe fittings. Pipe thread dimensions, when permanently established in the form of standard gauges, made so by the use of accurate subdivisions of the Imperial yard, though seeming to be an unnecessary refinement for so ordinary a class of work, really furnishes the means of extending the already well developed and recognized principle of modern manufactures, and which is "cheapness, serviceableness and quantitative accuracy."

Isolation of Calorific Rays.—F. van Assche places a drop of distilled and melted selenium upon a strip of glass, which is immediately covered by another plate of thin glass and the drop is compressed so as to spread it uniformly in a very thin, homogeneous layer. Care should be taken to avoid boiling the selenium upon the plate, as it would produce vapors, which, in condensing, form cells containing particles or crystals of selenium, between which light can pass without decomposition. When these precautions are taken, the chemical rays are reflected and the luminous vibrations are converted into electric energy; the calorific rays alone traverse the plate, after having undergone a certain amount of refraction. When the plate is heated to + 250° (482°F.), it appears to convert all the radiations into obscure rays. It can be utilized in various ways in the analysis of calorific rays: for example, in the experiments of Nobili and Meloni; in the photographic chamber, as an isolator, extinguishing all luminous and chemical radiations; by oculists, to shut out the rays of medium and of great refrangibility; and in the analysis of solar and lunar radiations. The coefficient of transmission is positive for heat, 0 for light, negative for the chemical rays. The greater the intensity of ordinary light the more completely it is suppressed by selenium.—*Comptes Rendus*, Oct. 15, 1883.

Interior African Sea.—Many persons have supposed that the French Commission, which was appointed to examine de Lessep's project, condemned it, but this is a mistake. The Yellow Book, published by the Ministry of Foreign Affairs, shows: 1. That the exactness of the scientific labors on which the project is based is beyond all question. 2. That the execution of the canal which is to be the

feeder of the future sea presents no difficulty. 3. That the work would be durable, since, even if we admit the most unfavorable hypotheses with regard to evaporation and saturation, the sea would have an assured existence of more than one thousand years. 4. That in no point of view could the sea be injurious, but that on the contrary, it would favor the development of colonization, by ameliorating the climate, diminishing malaria, and increasing the fertility. 5. Opinions have been divided as to the importance of the new route which would be opened to commerce, to the industry and security of Algeria; however, no one has been able, from any of these points of view, completely to deny the utility of the submersion of the basin of the Chotts. General Favé and others have eloquently set forth the capital importance of the interior sea, as well in a colonial as in a military point of view.—*Comptes Rendus*, April 16, 1883. C.

Propagation of Explosive Waves.—Berthelot and Vieille give the equation

$$\theta_1 = \theta_0 \sqrt{\frac{Q + q}{q}}$$

in which Q is the amount of heat set free at the moment of chemical combination; q, 273 times the specific heat; θ_1, the velocity of explosive translation of gaseous molecules; θ_0, the velocity of mean wave translation after the explosive wave has ceased to exert any influence. They have verified the formula, approximately, for a score of gaseous mixtures of very various composition. They think that in the act of explosion a certain number of molecules are thrown forward, with all the velocity corresponding to the maximum temperature developed by the chemical combination. This movement is transmitted from one inflamed edge to another, in a wave which is propagated with a velocity either identical or comparable to that of the molecules themselves.—*Ann. de Chim. et de Phys.*, xxviii. 293. C.

Tanning Linen.—A Belgian inventor, M. Piron, has invented a method of rendering cellulose tissues impermeable and very durable, without injuring their flexibility, and without much increasing their weight. By examining the bandages of the Egyptian mummies he inferred that the best preservatives would be found in the vegetable kingdom, and he has given preference to the green tar of birch bark, which furnishes the perfume of Russia leather. The tar forms, with alcohol, a solution of great fluidity; but when once dried it becomes

resinous and resists the solvent power of alcohol. It can be combined with the most brilliant colors. These qualities enable it to penetrate the capillary vessels of tissues, covering them with a varnish of great elasticity, which resists the corrosive action of acids, sea water and changes of temperature. The density is very small, so that the tissues are made impermeable with a slight increase of weight. The prepared stuffs can be folded without scaling. The aromatic odor drives away insects. Microscopic vegetation cannot grow, because neither air nor water can penetrate into the interior of the fibres. The invention can be applied to all vegetable tissues, such as sail cloths, cordage, awnings, curtains, etc.—*Chron. Industr.*, April 22, 1883. C.

Interior of the Globe.—Most of the mathematical investigations upon the figure and interior constitution of the globe, start from the hypothesis that it is entirely fluid, with the exception of a comparatively thin, superficial crust. Prof. Roche, of Montpelier, has shown that the hypothesis of complete fluidity cannot represent, within the limits of probable error, the polar flattening and the constant of equinoctial precession. He finds, however, that both of these facts are consistent with the hypothesis of an interior nucleus, with a density of about 7, and an external layer, with a thickness equal to $\frac{1}{6}$ of the semidiameter and a density of 3. This would give an interior mass with a specific gravity corresponding to that of meteoric iron, while the enveloping layer would be comparable, in density and constitution, to the stony äerolites.—*Comptes Rendus*, April 23, 1883. C.

Meteoric Dust.—While admitting that the brilliant sunsets may be partly owing to volcanic dust, Nordenskjold thinks that cosmical dust must also have played an important part. The snow which fell in the latter part of December, in the neighborhood of Stockholm, contained small quantities of black powder. Some of this powder was found upon analysis to contain carbon, which when burned left a reddish residium of oxide of iron, silex, phosphorus, cobalt and nickel. The quantity of cobalt and nickel amounted to half of one per cent. The Swedish Academy of Sciences has made an appropriation for conducting investigations, on a large scale, and at a distance from human settlements. Nordenskjold communicated this information to Daubrée, in the hope of awakening an interest which would lead to like investigations in the Alps, the Pyrennees, and the Jura.—*Les Mondes*, Feb. 2, 1884.

Liquefaction of Gases and Solidification of Bisulphide of Carbon and Alcohol.—Caillettet, in a note published in 1882, recommended liquefied ethylene as a means of obtaining an intense cold. Wroblewski and Olszewski have employed a new apparatus, which allowed them to submit considerable quantities of gas to pressures of several hundred atmospheres, so as to congeal bisulphide of carbon and alcohol and completely liquefy oxygen with great facility. By boiling ethylene in a vacuum they have obtained a temperature of — 136° C. (— 212·8° F.) Liquid oxygen is colorless and transparent, like carbonic acid; it is very mobile and forms a very marked meniscus. Bisulphide of carbon freezes in the neighborhood of — 116° C. (— 176·8° F.) and melts in the neighborhood of — 110° C. (— 166° F.). Alcohol becomes viscous, like oil, in the neighborhood of — 129° C. (— 200·2° F.) and solidifies in the neighborhood of 130·5° C. (202·9° F.), becoming a white body. Liquefied nitrogen is colorless, with a visible meniscus.—*Comptes Rendus*, April 16, 1883.

Book Notices.

HINTS ON THE DRAINAGE AND SEWERAGE OF DWELLINGS. By Wm. Paul Gerhard, Civil Engineer. New York: W. T. Comstock, 1884.

Again we are called upon to chronicle the advent of a new work on sanitary science; and that before us is well calculated to impress one with the magnitude that the branch to which it is devoted has grown.

In the first chapter the author quotes from an English report on filth diseases in which the following passage occurs: "Whether the ferments of disease, if they could be isolated in sufficient quantity, would prove themselves in any point odorous, is a point on which no guess need be hazarded; but it is certain that in doses in which they can fatally affect the human body they are infinitely out of the reach of even the most cultivated sense of smell, and that this sense (though it's positive warnings are of indispensable sanitary service) is not able, except by indirect and quite insufficient perceptions, to warn us against risks of morbid infection."

Such remarks would be superfluous were it not that the absence of odor appears to be regarded by the majority of persons as indicative of freedom from danger, and that the danger is proportioned to the offensiveness of the smell; apparently ignoring the fact that where persons

catch the most virulent diseases they have no direct intimation of danger until the symptoms manifest themselves. It is also to be remembered—even if the sense of smell were admitted to be reliable to detect dangerous emanations—that this sense is subject to the same inequalities in different individuals as the other senses, and is less likely to have the attention directed to its deficiency than in the case of sight or hearing.

Among the numerous methods and devices illustrated in the work it is impossible to decide at present upon the most effective, no doubt many will be found to be inefficient; a practical test under varying conditions being necessary in many cases to demonstrate their defects; but it is probable that some possess nearly equal merits, and among them there will result a sharp competition for favor.

As illustrating the recent developments of this comparatively experimental stage of sanitary appliances, the work under consideration is valuable. W. B. C.

THE AIR WE BREATHE AND VENTILATION. By Henry A. Mott, Jr., Ph.D., E. M., etc. Mott Series, No. 2. New York: John Wiley & Sons, 15 Astor Place. 1883. 81 pp.

This is a treatise upon the two subjects indicated in its title. The first part is a description, chemical and mechanical, of the atmosphere and its impurities, with some statements of the effect of the latter upon upon the health of the persons inhaling them.

The second part consists mainly of descriptions well illustrated with cuts of various patented devices for and systems of ventilation, in some cases evidently copied directly from the manufacturers' circulars.

The author lays special stress upon the advantages of ventilation by "aspiration," that is, of draining the foul air from the place to be ventilated, rather than of forcing fresh air into it, in which, on the ground of economy, a question which he does not discuss, he is no doubt correct; otherwise there does not appear to be much practical difference, for, if fresh air is forced in, the foul air must go out, and if the foul air is drawn out, fresh air will come in, and if the points of inlet under it are equally well placed the value of the result attained is not affected by the manner in which it is accomplished.

He advocates the placing of the exhausts near the ceiling rather than the floor, a point as to which there is a difference of opinion among good authorities. G. M. E.

List of Books added to the Library during October, November and December, 1883.

(Continued from page 32.)

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(To be concluded.)

Franklin Institute.

[*Proceedings of the Stated Meeting, held April* 16, 1884.]

Hall of the Institute, April 16, 1884.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair. There were present 159 members and 19 visitors.

The minutes of the previous meeting were read and approved. The Actuary submitted the minutes of the Board of Managers, and reports that at the stated meeting of the Board held Wednesday, April 9th, 18 persons had been elected to membership.

The Secretary, by instructions from the Committee on Science and the Arts, reported that the Committee having made the usual advertisement of its proposal, and having received no objections thereto, recommends the award of the John Scott Legacy Premium and Medal to the following persons, viz.: To Thomas Hall, of New York, for his improvement in Type Writers; to Joseph Bennor, of Philadelphia, for his improvement in Sewer Gas Traps; and to Horatio G. Eckstein for his improvements in Feed-Water Heaters.

On motion of Mr. Henry R. Heyl, seconded by Mr. Wm. B. Le Van, the recommendation of the Committee in the case of Thomas Hall was approved, and the Secretary was directed to prepare and transmit to the Board of City Trusts the usual communication to that effect. Similar action was taken in the cases of Messrs, Bennor and Eckstein.

Mr. Robert Grimshaw, of New York, presented a paper entitled "To Chicago in Eighteen Hours," which, with the discussion thereon, has been submitted for publication.

The Secretary's report embraced remarks on the Waste of Fuel, the Preservation of Forests, and a comparison of the growth of the Coal and Iron industries of Great Britain and the United States. Of the mechanical novelties described, the most interesting was the Siemens Regenerative Gas Light, of which an illustrated description is in course of preparation for publication.

William H. Wahl, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVII. JUNE, 1884. No. 6.

THE CHEAPEST POINT OF CUT-OFF.

BY WILLIAM DENNIS MARKS,

Whitney Professor of Dynamical Engineering University of Pennsylvania.

In reply to Professor De Volson Wood's criticisms on what I have had to say regarding economy of steam, I will compare only what Prof. Wood has written with what I have written.

In this JOURNAL, January, 1884, Prof. Wood says:

"It is proper to observe that in Prof. Marks' analysis of this problem in the last December number of this JOURNAL, that the constant charges are assumed to be a constant fraction of the cost of steam;" also, "The solution then is not general but *special*, and we may draw the inference that the point of cheapest cut-off is *generally* dependent upon the constant charges."

Prof. Wood does not sustain the first statement or even refer to it in his last paper.

Is this fair? One of us was wrong. Which is it?

In this JOURNAL for February, 1884, I say:

"The question squarely at issue between myself and my critics is this:

"*Do the constant charges have the effect of making the cheapest point of cut-off later than it would appear to be from a purely physical consideration?*

"I have asserted, and believe I have proved, that they do not. I

would further add that I am convinced that the ratio existing between the actual steam from boiler and the steam by the indicator diagram in no wise affects this question.

"More knowledge of the law of this ratio may affect the point of cut-off, but will not involve the constant charges."

May I beg the reader to mark this statement? It is all that is at issue, and other questions that may be raised are not pertinent to the point at issue.

Prof. Wood says that there is a difference between the "designer's problem" and the "owner's problem." I do not recognize such a distinction. The first problem, the problem which I have essayed to solve, is how to get a certain horse-power with the least possible expense. There is another problem, which is, how to make the best of an existing plant which is not adapted to the requirements of its work, but this is a *special* problem, requiring a special knowledge of the existing machinery, and cannot be treated generally.

In this JOURNAL for December, 1883, I say:

"The gain by increasing the expansion from eight to nine times is but a theoretical one per cent. at the outside, and possibly there is an actual loss.

"The theoretical minimum results for condensing trials are not closely calculated because they do not surely indicate accurate attainable results, but serve merely to show in what direction progress must be made.

"Right here our knowledge is deficient, and we must have more data regarding condensation before attempting to accurately predict real results at high expansions.

"Concentration of power is lost with increasing economy of steam. It is a very important attribute of the steam engine, bearing directly upon its efficiency as a machine."

Right in the face of these statements Prof. Wood attributes to me the following ideas:

"The problem before us, then, is the *designer's* problem, and not the *owner's* problem.* John Doe having confidence in the Professor,

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* The *designer's* problem consists in making an engine which will deliver a given number of horse-powers most economically; the *owner's* problem consists in delivering the greatest number of horse-powers from a given plant with the most profit to the owner. When the designer has properly solved his problem, it is merged into that of the owner's.

secures his services in selecting the engine which will be the most economical for delivering 150 horse-powers for ten years. From the known initial pressure (say 90 pounds), the back pressure (say 5 pounds), and the clearance (which he assumes to be small), he finds by means of equation (8)

$$e = \frac{B}{P_b} = \frac{5}{90} = \frac{1}{18},$$

for the approximate value of the cut-off; and for a more accurate value

$$e = \frac{B\left[1 - b\left(1 - \log_e \frac{b}{k}\right)\right]}{P_t} + \frac{B}{k - b\,p_t \log_e \frac{1}{e}}, \qquad (7)$$

which for want of data we cannot reduce numerically, and hence will assume it as $\frac{1}{17}$, or even $\frac{1}{16}$. These men go into the market, and with the given data, the Professor selects the engine that will produce the 150 horse-powers "*by using the least possible steam per horse-power per hour;*" excepting that, for commercial reasons, he quietly uses a cut-off of $\frac{1}{16}$* as the basis of selection."

The whole problem is a "commercial" problem. I do not reduce the number of expansions because of the *constant charges*, as might be inferred from Professor Wood's language, but for the reasons quoted above.

Is Prof. Wood fair in ignoring a limitation to expansion of steam which I mathematically deduced from physical data, and then stated in plain English?

He has no right to attribute to me absurdities in the way of $\frac{1}{16}$ or $\frac{1}{17}$ cut off under conditions less favorable to extreme expansions than the conditions from which I deduced a limit of 8 or 9 expansions.

In this JOURNAL, February, 1884, I say:

"Reference to my paper will make it clear, I trust, as to how the point of cut-off affects the weight of steam per horse-power per hour, and also fix the limits within which physical laws confine the expansion of steam."

Professor Wood writes as follows:

"*Doc.* The question of the cut-off grows in interest. I see our Professor says: 'The point of cut off has, practically, nothing to do with the constant charges, save so far as it determines the volume of the cylinder required.'

* JOURNAL FRANKLIN INSTITUTE, Dec., 1883, and Jan., 1884, p. 41.

"*Smith.* I do not presume to understand all that is written about the cut-off; but there is something amusing in this statement of the Professor. As before, he denies one proposition, and then, in my opinion, admits another element which opposes his denial; for in my opinion, the size of the cylinder, involving as it does the cost of the engine, does affect the economical point of cut-off by making the constant charges, so called, different from what they otherwise would be; for the truth of which I appeal to you in the case of the two engines now before you. The consideration of the theoretical effect of constant charges, I leave to the Professor."

The constant charges are:

(1) Interest on deterioration of and repairs to engine.
(2) Wages of fireman and engineer.
(3) Cost of oil and waste.
(4) Interest on deterioration of and repairs to boilers.
(5) " " " shelter.
(6) Taxes and insurance on machinery and buildings.

Of all these different items there is but one that is a function of the size of the cylinder; it is the interest on deterioration of and repairs to the steam cylinder. I will even say; although it is *not correct;* for the sake of having the same premise in our argument, the interest on deterioration of and repairs to the *engine.* What does it amount to? Are our brethren, the marine engineers of England, a set of dolts, who have made their ship owners rich by piling cylinder on cylinder, and carrying the expansion of steam to its utmost physical limitations in cylinder after cylinder?

Could anything be more unfair than to endeavor to make me acknowledge in his dialogue the difference in interest on the cost of the steam cylinders, or even of the engine, as the controlling element of cost in the constant charges? It is a trifle not worth noticing, and all experience has so proved it. Surely that engine requiring the least steam per horse-power per hour demands the least cost for boilers and appurtenances.

Will Prof. Wood be so good as to give some actual case in place of the subjoined paragraph?

"*Doe.* Not necessarily so, for it might be *economy* to *lose* on the fuel and save the cost of enlargement. Suppose that the interest, repairs, etc.—"constant charges"—are 16 per cent. on this purchase, I would

save \$160 per year if the smaller engine will answer. If my boilers are somewhat under size, perhaps \$50 per year extra in fuel will supply the steam, in which case there will be a decided saving. Please examine these specifications of my boilers and inform me if they have sufficient capacity for the smaller engine."

Professor (after figuring). They will answer.

Doc. The boilers being out of the question, does it not follow, from your own reasoning, that it may, and probably will, be more economical for me to purchase the smaller engine.

Professor. Well, it appears so; but I still assure you that *the larger engine will give you the* 150 *horse-powers with less cost for fuel than the smaller one.*

Will Prof. Wood be so fair as to take the ordinary case where the boilers are in question?

Does Prof. Wood mean to imply that the experimental figures for weight of steam given by the Buckeye Engine Company, or by Mr. Barrus, are a result of the constant charges?

Professor Wood should remember that his thesis is "the point of cheapest cut-off is *generally* dependent upon the constant charges."

I do not dispute the accuracy of the physical constants obtained by Mr. Thompson and Mr. Barrus; they are valuable additions to our experimental physical knowledge and will be more valuable when we know the size of cylinder, the number of strokes, the quality, temperature and pressure of the steam, and whether the engines were condensing or non-condensing. Professor Wood writes as follows:

"It is unnecessary to argue this point; it is only necessary to convince you that these so-called "constant charges" are variables in the process of designing, to cause you to abandon your rule, giving as it does a cut-off of $\frac{1}{10}$ to $\frac{1}{20}$, which you have insisted up to the present time to be "practically accurate within the widest range," after establishing certain relations in regard to the steam. (Jan., 1884, p. 1.)"

I say, January, 1884, JOURNAL OF THE FRANKLIN INSTITUTE:

"What is needed to render this rule *practically accurate within the widest range*, is to establish the ratio which exists between the steam furnished by the boiler and that recorded by the indicator diagram, under all the various conditions as to initial and back pressures, and points of cut-off used."

Could what I said as a qualification be more garbled?

In this JOURNAL for February, 1884, I wrote as follows:

"The proportion from which equation (5) is derived is this:

"cV: eV:: constant charges per day (C); cost of steam per day for a cut-off, e, and a given horse-power.

"c is not a constant, as stated by Prof. Wood, nor is it said to be a constant in my paper; it is a function of the mean effective pressure.

"If fallacy there be in what I have written, it must be found in the above proportion.

"The mere assertion of so distinguished a mathematician as Prof. Wood carries so much weight that it is a duty which he owes to himself and to the writer to give the most careful consideration to the point at issue, and either prove the writer's error unmistakably, or to fairly acknowledge his own, in as public a manner as he has seen fit to publish his condemnation.

"It is a question that not only involves himself, but also all his colleagues giving instruction in engineering in the Stevens Institute."

Has Professor Wood referred to equation (5) in his last paper after criticizing it so severely in his first paper? Has Professor Wood been just in avoiding an acknowledgment of his own mathematical blunder?

I have endeavored to meet every important scientific point raised in Professor Wood's paper by reference to, and quotation of, published statements.

If I have omitted any which Professor Wood deems important I shall be pleased to discuss them at length if he will be so good as to direct my attention to them. I confess I have been considerably at a loss to comprehend why Professor Wood should have adopted the platonic literary style of his last paper. Unless because it affords him a convenient method of making his opponent say that which he desires to have him say, and thus expose himself to mis-construction and criticism. If he will be kind enough not to speak for me but directly for himself I will be pleased to treat the scientific discussion soberly and fairly and himself courteously.

I see no reason to alter the following statements. Jour. Frank. Inst., February, 1884:

"*In other words, John Doe must determine the most economical point of cut-off for his particular case from purely physical considerations, and then, if he can, buy an engine which will do his work with that cut-off with the least amount of constant charges.*

"*He will be wiser if he anticipates an increase of business to choose a cut-off a little too early rather than too late for greatest economy.*"

"This same point was mathematically stated in my letter of Oct. 20, 1883, to the *The American Engineer*, with the remark: 'If I am correct in my premises, the method of Professor Rankine, as well as the papers of Messrs. Wolff, Denton and Weightman, and of Professor Thurston must be valueless.' There has been no proof, of any practical value, given to the contrary of this assertion, or of my original position in this Journal, June, 1880, save such limitations as I have myself established December, 1883."

"*In either case, John Doe's only opportunity to save money lies in saving steam per horse-power per hour*, and the greater the power used the more money he can save by proper attention to the point of cut-off. It is right here that these gentlemen—Professors De Volson Wood and Thurston, and Messrs. Wolff, Denton and Weightman—have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded."

In the preceding discussion I have in fairness to Professor Wood confined myself to my published papers anterior to March, 1884. Since that time [JOUR. FRANK. INST., March and April, 1884] I have published a paper on "Initial Condensation" which possibly may throw more light on the law of the condensation of steam inside of the steam cylinder.

These papers have, in a collected form, been for some time in Professor Wood's possession, and I am justified in assuming that he permits his present critique to be published with a full knowledge of what I have written, since he has done me the honor to criticise my earlier writings.

I will end this argument by saying, that acceptance of authority, however high, makes an end of scientific progress.

Rankine's genius enabled him to step from peak to peak of knowledge leaving us to toil through the dark valleys between as best we may. Is it not possible however that the very rapidity of his progress has caused him to overlook important conditions and limitations of the principles which he enunciated in rapid succession? May it not be that his delighted and dazzled followers have not been as circumspect as they would be under different circumstances, or in accepting the authority of a less brilliant leader?

Nature is no shallow fountain to be exhausted in any direction by the most profound of her students, and each new discovery but opens new vistas into the infinite field of knowledge that lies before us.

Nor do I wish to be understood as failing to render to Professors Thurston and Wood that tribute of gratitude and admiration which is due to them from all engineers. Their talent, their industry, and their wide and varied knowledge, has been known for a score of years, and they have been foremost in the advancement of the standing of the engineering profession in many ways. No denial of mine, did I desire to make such denial, would detract from their well-earned right to the title of leaders in engineering research.

Criticism which I have been forced to make of the writings of these gentlemen has ever been in self defense. I would gladly have gone my own ways and left them unmolested, however much my opinion or my deductions might have differed from theirs. My language has been positive because the laws of nature are precise. I cannot follow them and evade plainness of speech.

Taking Professor Wood's article as the work of a professor not applying himself as an investigator of natural laws, but as the act of an advocate, I cannot deny his ability as a dialectician. Professor Wood is, however, incapable of not perceiving what lies beneath his argument, or of overlooking many points that he has not noticed. While he is thus intellectually incapable of not perceiving his suppression of half the truth and his zig-zag evasion of difficulties, maybe he regards his course as a subdivision of labor in the cause of truth and thus justifies it?

The ardor of a friend too may plead his defense for having overleaped the bounds of natural laws, and forgotten the philosophic circumspection of a scientific investigator.

No word of doubt or hesitation mars Professor Wood's appeal to popular sentiment and no one knows the efficiency of this course better than himself. He represents matters of opinion as undoubted truth, and he neglects undoubted truths where not suitable to his purpose. Is his paper worthy of himself or of a place in the first rank of authority?

In order not to misrepresent Professor Thurston's attitude in the present discussion, it is but right to quote his words in a letter to the writer, April 16, 1884, regarding initial condensation.

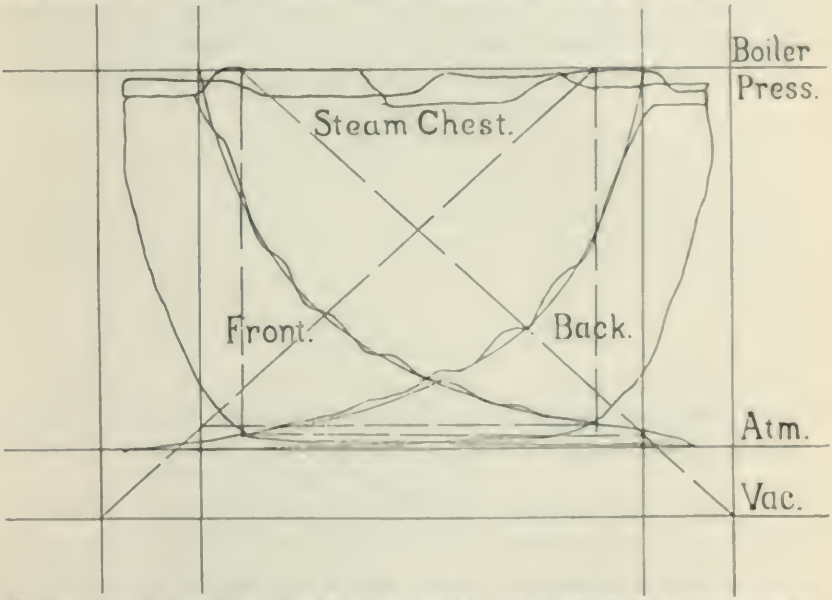
"If it should prove that the functions are of the form you have assumed you will have earned the credit of their first publication. In any event you have been the first to indicate plainly the correct method of seeking the needed quantities, and to make an effort to obtain the

coefficients in a correct manner, for I intentionally left it indefinite in my papers. I shall hope before the summer is over to get at the real thing approximately if not exactly."

It would be hard to over-estimate the generosity and candor of these words or the pleasure it affords the writer to meet Professor Thurston on common ground in the search for scientific truth.

The following analysis of a pair of indicator diagrams will illustrate a phase of the law of condensation of steam in which the ratio between the actual and the indicated steam seems to become a constant and a minimum for all points of cut-off.

The writer owes the diagrams to the thoughtful courtesy of Mr. J. Vaughan Merrick, of the Southwark Foundry, Philadelphia.



Porter-Allen Engine. Post-office Building, Philadelphia, March [illegible], 1884. Scale 40 pounds per inch

Engine non-condensing.
Stroke 24″ = 2 ft.
Clearance 4½ per cent. of stroke = 0·09 ft. deduced from expansion curve
Diameter 14½″ = 1·208 ft.
Abs. Initial pressure, back end, 87 lbs.
" " " front end, 89 lbs.
" " " mean, 88 lbs.
" back pressure at midstroke, 16 lbs.
Temperature of initial steam, 318·45 deg. Fahr.
Specific vol. of initial steam, 3·008.

Temperature exhaust steam, 216·29 deg. Fahr.
Number of strokes 400 per minute.

$$\left.\begin{array}{lll}\text{Mean eff. pressure, front end} & = & 20{\cdot}62 \\ \text{" " " back end} & = & 17{\cdot}24 \\ \text{" " " mean} & = & 18{\cdot}93\end{array}\right\}\text{Amslers' Polar. Planimeter used.}$$

Indicated horse power = 74·91.
Max. back pressure = pressure at cut-off.

$$\left.\begin{array}{l}(e)\ \text{Point of cut-off, front end} \\ \text{" " " back end}\end{array}\right\} = 0{\cdot}168 \text{ mean value.}$$

(k) Clearance (true) 0·043.
Cut-off less compression (e—k) 0·125. = $\frac{1}{8}$.

$$\text{Indicated steam } \frac{859375}{300{\cdot}8 \times 18{\cdot}93 \times 8} = 18{\cdot}86 \text{ lbs. per horse-power per hour.}$$

Since the back pressure reaches the initial pressure we can reasonably assume that the condensation of the piston and cylinder heads disappears entirely or is greatly reduced, therefore equation (8) JOURNAL FRANKLIN INSTITUTE, March 1884, assumes the following form:

$$r = 1 + \frac{S(T_b - T_e)}{62\frac{1}{2}N} C \frac{4}{d}.$$

If we let $A = \frac{62\frac{1}{2}}{S}$ and $D = \frac{T_b - T_e}{N} C$

we have

$$r = 1 + \frac{D}{A} \frac{4}{d}$$

In the present case $A = {\cdot}207$

In the present case $D = {\cdot}0025$ if we assume $C = \frac{1}{100}$ lb. from Harris-Corliss Engine. J. F. I., March, 1884.

$$r = 1 + \frac{{\cdot}0025 \times 4}{{\cdot}207 \times 1{\cdot}208} = 1{\cdot}04.$$

Therefore the actual water from boiler is $18{\cdot}86 \times 1{\cdot}04 = 19{\cdot}61$ lbs. per horse-power per hour. This of course makes no allowance for losses in pipes and by radiation, but only for the loss by the unavoidable internal cylinder condensation, assuming dry saturated steam to reach the cylinder.

The fraction of the stroke b, at which the exhaust port closes is ·236 from the nearest end.

Rendering fixed the condition that the exhaust steam shall always be compressed to the initial pressure, and seeking the cheapest point of cut-off, we have a modified form of eq. (16) (J. F. I., March 1884).

$$e = \frac{B\left[1 - b\left(1 - \text{nat. log.}\ \frac{b}{k}\right)\right]}{P_b} + k - k \text{ nat. log.}\ \frac{1}{e}$$

From the data we have

$$\frac{B\left[1 - b\left(1 - \text{nat. log.}\ \frac{b}{k}\right)\right]}{P_b} = 0{\cdot}212$$

$$k = 0{\cdot}043$$

Assume $e = \frac{1}{4}$ we have

$$0{\cdot}25 = {\cdot}212 + {\cdot}043 - {\cdot}059 = {\cdot}196.$$

Assume again $e = \frac{1}{5}$ we have with sufficient accuracy

$${\cdot}20 = {\cdot}212 + {\cdot}043 - {\cdot}069 = {\cdot}186.$$

About $\frac{1}{5}$ cut-off then proves the point of cheapest cut-off under existing circumstances.

This is the true cut-off and includes clearance.

Under existing circumstances the point of maximum economy is slightly overrun, but the engine will, in all probability, have an increased load put upon it and cut-off later in the stroke than 17 per cent of the volume. As installed greater economy cannot be reached by the engine, and the end of any possible economy by expansion is reached.

The perfection of the expansion and compression curves would seem to indicate tight valves and piston.

There was evidently an interval sufficient to permit a change of the regimen of the engine between the taking of the steam chest diagram and that from the back end of the cylinder.

I do not know that I have ever seen diagrams more completely fulfilling all the mechanical and economic conditions of a high speed non-condensing engine of small size.

It is of interest to observe from the formula that the condition placed that the compressed exhaust steam shall reach the initial pressure renders the ratio of the indicated to the actual steam a constant, for all points of cut-off.

The steam chest diagram by its sudden drop and rise shows this condition not to have been precisely fulfilled, but it is doubtful if the exact fulfillment of such a condition can be demanded of any engine in actual use for ordinary purposes.

Philadelphia, May 9, 1884.

TURBINES.

By DeVolson Wood.

The chief object of this communication is to pass a criticism upon Professor Rankine's treatment of turbines as given in his work on the Steam Engine and other Prime Movers, pp. 189–199. If my audience were before me with book in hand, it would require but a few words to explain the matter, but considering it to be scattered, and variously limited as to time for the study of the question, I will analyze it in detail.

On page 195 of the work referred to is the statement: "The above are general expressions for all turbines with guide blades;" which, being without qualifications, might be taken literally as applicable to turbines of all manner of construction and run at any speed. But in fact the author has so restricted the problem that it can apply only to the three classes—outward flow, inward flow and parallel flow—and further, that each of these classes must be constructed in a particular way, and run at a certain definite speed. Thus, he states, on page 191, "In treating of the efficiency of the turbine, it will be assumed that they are constructed of the forms and proportions, and worked in the manner most favorable to efficiency, according to rules which will presently be explained." These rules are few in number, and restrict the wheel to a special kind.

In attempting to treat of the three classes of turbines as one, Rankine is obliged to construct language so that it will be equally applicable to any one of them, and although much is gained in generality in the analysis by this process, yet something is sacrificed to definiteness of expression and idea. We prefer to confine the attention, at first, to one form only, and for this purpose choose the outward flow wheel, after which the notation may be so interpreted, if possible, as to apply to other forms. In Rankine's treatment, the energy of the water due to its descent while in the parallel flow wheel is neglected, which, in many cases, is too important to be neglected.

The rules given by Rankine for the outward flow turbine are: "The first element, E, of the vane EL of the wheel must be normal to the inner rim EG, and hence will be radial," page 190. "The wheel shall be so constructed that the radial velocity of the water through it shall be uniform;" "The wheel shall have such a speed as that

the tangential velocity of the water on entering the wheel shall equal the velocity of the inner rim of the wheel;" "The tangential velocity, or velocity of whirl *relatively to the wheel*, on leaving the wheel, shall be equal and contrary to that of the outer rim of the wheel; and the wheel passages must be constantly full," p. 193. Adopting the notation of the author, we have $r = OE =$ the radius of the inner rim of the wheel, $nr =$ the radius of the outer rim, where the water quits the wheel, $a =$ the angular velocity of the wheel, ar and $nar =$ the two rim velocities, $\alpha = FEA =$ the angle between the last element of the guide plate CE and the inner rim GE, $\beta = KLH =$ the angle between the last element of the vane EL and the outer rim HL. $V =$ the actual velocity with which the water enters the wheel, $v = V \cos. \alpha =$ the tangential component of the velocity, called by Rankine the velocity of whirl, and $w =$ the velocity of whirl *relatively to the vane.*

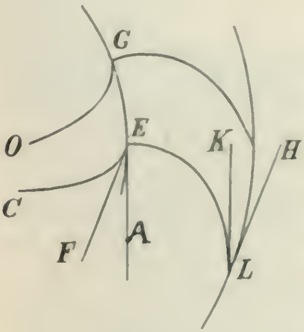


Fig. 1.

Then, since the velocity of whirl on first entering the wheel is to equal the velocity of the wheel at that point (top of page 193), we have

$$v = ar \qquad (a)$$

and since the water is to leave the wheel without whirl (bottom of page 192),

$$w = nr, \qquad (b)$$

and since the radial velocity is to be uniform (p. 192),

$$\tan. \alpha = n \tan. \beta; \qquad (c)$$

which equations are the same as those of the author.

It is a principle of mechanics that when the forces of a system consist only of the mutual actions and reactions between the parts of the system, the moment of the momentum will be constant during the motion. In the turbine acting without impulse, and friction being neglected, the motion is produced by pressure between the water and floats, and hence the above principle is applicable, and the moment of the momentum lost by the water will be imparted to the wheel. This is the principle used by Rankine, pages 193 and 194.

If $m = DQ \div g$, be the mass of water flowing through the wheel in a second, then will the moment of the momentum of the water on entering the wheel be

$$mvr \tag{d}$$

which is the author's equation at the middle of page 194. Whatever be the velocity of the wheel, the tangential velocity with which the water quits it, will be

$$nar - w, \tag{e}$$

which is the next expression given by the author. But now he substitutes nv for w (equation (b), making

$$nar - w = n(ar - v). \tag{f}$$

But it is not *generally* true that $w = nv$, and is true only for a particular speed; and in this case the particular speed is given by equation (a) which will reduce (f) to zero. The author's equations (2) and (3), page 194, are, therefore, not *generally* true, and are true only for $v = ar$; and this value reduces the author's equation (3) to

$$Ma = mvra, \tag{g}$$

where M is the moment of a couple. This result follows directly from our equation (d) by multiplying it by a, and may be reduced by means of equation (a) to

$$Ma = mv^2. \tag{h}$$

It is worthy of note, in passing, that the dynamic effect in this case is *twice* that due to the kinetic energy of the water, and hence one-half must be due to direct pressure; and if the entire effect of the water were utilized by the wheel, the head due to the velocity of the water entering the wheel would be one-half the head in the supply chamber, but as there is inevitably a loss, the head due to that velocity will be less than one-half the total head, the exact value of which will soon be found.

Passing now to page 195, and following the *method* of the author, considering the total energy expended as divided into several heads; we have, h_1 the head due to the tangential component of the velocity as it leaves the guide plates; h_2 the head due to the radial component of the same velocity, called the velocity of flow, and these added will be the head due to the velocity with which the water issues from the gates; h_3 the head due to the tangential component of the velocity with which the water enters the vanes of the wheel *relatively to the*

wheel; then as the water is passing through the wheel we have h_4 the head due to the action of the wheel on the water, which, being an energy imparted by the wheel to the water, will be negative; h_5 the head due to the tangential component of velocity, or velocity of whirl *relatively to the vane* as it quits the wheel, called the reversed relative velocity of whirl; then as the water quits the wheel we have, h_6 the radial component of the actual velocity with which the water quits the wheel, and h_7 the tangential component of the same, or the final velocity of whirl. The values of the several heads, for the conditions prescribed by the author, will be

$$h_1 = v^2 \div 2g, \qquad h_5 = u^2 \div 2g,$$
$$h_2 = v^2 \tan.^2 \alpha \div 2g, \qquad h_6 = n^2 v^2 \tan.^2 \beta \div 2g,$$
$$h_3 = 0, \qquad h_7 = 0,$$
$$h_4 = -(n^2 r^2 a^2 - r^2 a^2) \div 2g = (1 - n^2) r^2 a^2 \div 2g.$$

But h_6 is not only the same as h_2 in value, but as the wheel is constructed and operated, one is simply the repetition of the other, and hence one of them must be suppressed, and in order to conform with the notation of the author h_2 will be canceled. Hence we have for the head in the supply chamber

$$h_0 = h_1 + h_5 + h_4 + h_6 + h_7 = h.$$
$$= [(1 + n^2 + n^2 \tan.^2 \beta) v^2 + (1 - n^2) a^2 r^2] \div 2g. \qquad (1)$$

which is the author's equation (1), page 195, and thus far the analysis is correct. But we observe that this equation is true only for the wheel as made and when run with the velocity $v = ar$. Were it not so run as to make the final tangential velocity zero, h_7 would have a finite value, and if the wheel were not constructed for a uniform radial flow h_2 and h_6 would not be equal, and were it not constructed and run as described, we would not have $h_7 = 0$, nor $u = nv$. Now making $v = ar$, equation (1) becomes

$$h_0 = (2 + n^2 \tan.^2 \beta) v^2 \div 2g. \qquad (2)$$

which is the author's equation (2), page 196.

We claim that Rankine errs in all his analysis where he considers ar as different in value from v; that on page 195 following equation (6) it should read: The above expressions are true for the three classes of turbines, when constructed as described, and run with the velocity $v = ar$ as stated; that all his equations on pages 195 to 200 are erroneous except within the above conditions; that the solution of reaction

wheels, Article 176, is far-fetched if not logically inaccurate, wherein he makes $nr = r_1$ after assuming $r = 0$, and, similarly, nz finite after assuming $z = 0$, although his final result is correct; that it is a mere fortunate coincidence that the results on page 199 "agree exactly with experiment." This last conclusion, by the author, is remarkable, in face of the fact that experimental results are always more or less discordant. The fact that the efficiency of a turbine is near the maximum for quite a range of velocities, doubtless aided in this remarkable verification of the formulæ.

The fact that equation (i) is not general, might be inferred from the results of an attempt to discuss it. Thus, h_0 being constant for any particular case, v must vary inversely as a, and would be a maximum for $a = 0$, in which case the wheel would be at rest; but it is known that the resulting value for v is not only erroneous, but that the general result is incorrect, for it is true that v increases with a up to a certain limit. Again, a would be a maximum for $v = 0$, a result strikingly absurd. It is hardly necessary to examine these conditions further, but we notice the fact that according to the author's equation 7 (page 195) for parallel flow turbines, the head due to the velocity of the water at entrance is independent of the velocity of the wheel, a result which would also be very absurd had he not previously established the condition that $v = ar$.

The following is all the analysis necessary for finding the efficiency of the turbine described by Rankine, when run with the velocity $v = ar$. The moment of the momentum of the water on entering the wheel will be

$$mvr$$

and this will be the entire moment of the momentum, imparted to the wheel since there will be no final velocity of whirl; and the work done by the wheel on this account, per second, will be

$$Ma = mvra = mv^2. \qquad (k)$$

The total energy due to the head in the supply chamber will be the energy imparted to the wheel *plus* the energy lost by the final velocity of flow. The value of the latter will be

$$\tfrac{1}{2}mn^2v^2 \tan.^2\beta; \qquad (l)$$

hence the total energy due to the head will be the sum of (k) and (l), or

$$Wh_\circ = \tfrac{1}{2}m(2 + n^2 \tan.^2 {}_1\beta)v^2$$

where W is the weight of the mass m; hence

$$h_\circ = (2 + n^2 \tan.^2 {}_1\beta)\frac{v^2}{2g},$$

and the maximum efficiency will be

$$\frac{Ma}{Wh_\circ} = \frac{2}{2 + n^2 \tan.^2 {}_1\beta}$$

It will be observed that in this brief solution no reference has been made to centrifugal force, and yet the same result has been obtained as by those who resolve the problem by other methods. In fact, in motors receiving their power from the energy of the fluid passing through them, the actual centrifugal force is self-neutralized; for it is energy imparted to the water by the wheel, and hence primarily at the expense of the energy of the outflowing jet; but when the water which has received this energy escapes it will impart to the wheel the energy which it has thus acquired. Or, to put it in another light, if it were possible for the outflowing water to impart this increased energy to the water in the wheel and at the same time prevent it from imparting its energy to the wheel, the wheel could not do as much work as it would if the centrifugal force were neutralized. Thus, if water

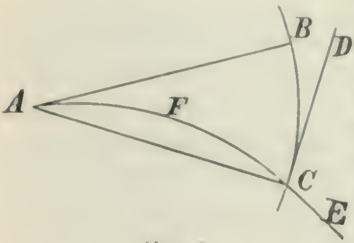


FIG. 2.

flows from A to B along a radial arm in the same time that the arm rotates from AB to AC, the actual path of the water will be some curve, AFC, longer than AC, and hence the velocity imparted to the water will be greater than if its path had been AC in space; but if the water escapes in the direction CD, normal to AC, in the former case it will be deflected through the obtuse angle ECD, while in the latter it will be deflected through a right angle. Generally, the greater the angle of deflection of a jet (less than 180°), the greater the pressure exerted in the opposite direction; hence the stream whose actual path is AFC will exert a greater pressure on the arm at C in the direction DC, than if the path were AC in space; thus compensating for the energy expended in producing an increased energy. This view of the case may remove a difficulty sometimes met with in the compara-

tive study of Barker's mill and the Whitelaw (and Scottish) turbine. In the former the water is carried around in the arms, while in the latter the water may be, comparatively, at rest in the body of the wheel in reference to the earth. The greater efficiency of the latter is due chiefly to the reduction of friction and of *whirls* in the wheel, and not to the difference in the actual centrifugal force of the water.

These motors may all be analyzed by means of the principles of energy, and without involving the idea of centrifugal force, and the true action of the water may, in some cases, be more clearly seen by this mode of treatment; while, on the other hand, every change of direction of a moving body may be considered as the result of a centripetal action on the body, the equal opposite of which is centrifugal. But either of these modes of disposing of the principle offers no explanation of its use as employed by the most eminent writers. On page 195 of Rankine's work, above referred to, is the expression, "to balance centrifugal force, the head

$$a^2 r^2 (1 - n^2) \div 2g,"$$

and Wiesbach and many other authors give the same analytical expression for the effect of the centrifugal action. But the correctness of this expression has been called in question by different writers, chiefly on the ground that the water flowing through the curved passages of the wheel does not have the angular velocity of the wheel, as may be seen by articles in the last August number of this journal, page 92, and also in the September and December numbers.

We, therefore, first of all examine its correctness. The principle to be considered may be stated thus:

A particle, mass m, in a tube has an initial velocity c_1 *along the axis of the tube, while the tube rotates with a uniform angular velocity; required the subsequent velocity of the particle.*

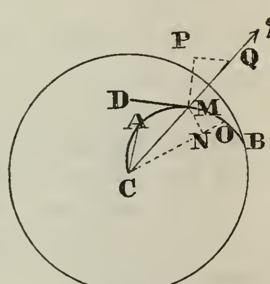


Fig. 3.

Let $CAMB$ be the tube rotating about a vertical axis through C, and at any instant, t, let the particle be at M; A the initial position when the particle has an initial velocity, c_1, *relatively to the tube*, and B the terminal position where the velocity is c_2 also relatively to the tube. Also let

$\omega =$ the angular velocity of the tube about C,

$r_1 = CA$, $r_2 = CB$, $\rho = CM$, s = any portion of the arc AMB, $ds = MO$, $d\rho = NO$, v_1 = the circular velocity of the disc at $A = r_1\omega$, v_2 = the circular velocity at $B = r_2\omega$.

To find the law of the force acting on the particle conceive, at first, that the particle is held at M so as to be at rest relatively to the tube while rotating with the tube; there will be an outward pull on the axis C due to the centrifugal force of the particle, the expression for which is

$$\varphi = m\omega^2\rho.$$

If the restraining force be withdrawn, that component of the centrifugal force parallel to the tangent of the tube at that point, will produce motion along the tube, while the component normal to the tube will simply produce a pressure against the side of the tube. Let $MQ = \varphi$, draw MP perpendicular to the tangent DM, and QP parallel to it, MN perpendicular to the radius vector CO, and let $QMP = \theta = NMO$, then

$$PQ = \varphi \sin. \theta,$$

and, according to Newton's second law, we have

$$m\frac{d^2s}{dt^2} = m\,\omega^2\rho \sin. \theta. \qquad (m)$$

But from the figure, *ultimately*,

$$ds \sin. \theta = d\rho,$$

which, multiplied by the preceding equation, member by member, and equal factors canceled, gives

$$\frac{ds\, d^2 s}{dt^2} = \omega^2\rho\, d\rho,$$

and integrating,

$$\left.\frac{ds^2}{dt^2}\right]_{c_1}^{c_2} = \left.\omega^2\rho^2\right]_{r_1}^{r_2} \qquad (n)$$

or $$c_2^2 - c_1^2 = \omega^2(r_2^2 - r_1^2) = v_2^2 - v_1^2; \qquad (o)$$

also, $$\tfrac{1}{2}m\,c_2^2 - \tfrac{1}{2}m\,c_1^2 = \tfrac{1}{2}m\,(v_2^2 - v_1^2). \qquad (p)$$

The left member of the last equation is the energy gained or lost, *relatively to the tube*, there being a gain in moving away from the centre, and a loss when moving towards it. Hence

The energy gained or lost, RELATIVELY TO THE TUBE, *by a particle moving in a tube rotating uniformly about a vertical axis,* the change of velocity of the particle being due solely *to the pressure of the walls of*

the tube against the particle, equals one-half the mass of the particle into the difference of the squares of the circular velocities of the tube at the initial and terminal points of the path of the particle. Also,

The RELATIVE ENERGY *gained or lost is independent of the form of the path,* and dependent only upon the radii vectores of the initial and terminal points, and the angular velocity of the tube. Hence, also,

The ACTUAL ENERGY, *or energy in reference to some object considered fixed, as the earth, will depend not only upon the* VELOCITY RELATIVELY TO THE TUBE, *but also upon the direction of the tube in reference to the radius vector at that point,* and *the actual velocity of the tube at that point.*

The first of these inferences is similar to that of the energy gained by a body descending under the action of gravity from one level to another along a fixed path, where the change of energy is dependent only upon the difference of heights.

The second inference is only another wording of the former, in which the energy gained is independent of the path.

The third inference is similar to that of a body descending along a path in motion, where the actual energy is dependent upon both the relative velocity along the path and of the path itself.

The equation of the path of the particle in space will depend upon the equation of the tube relatively to the rotating disc, as well as upon the motion along the tube. If the particle be at M and in an element of time, dt, it moves along the path to O, the result will be the same as if it moved from M to N in a circular arc, and thence to O along the radius vector CO. The tube having a rotary motion, assume that the point M is carried forward in a circular arc to A in an element of time, a distance $= \rho\omega dt$, where $\rho = CM$; then will the final position be the same as if it moved from M to A, thence from A to B, the distance $AB = MN$, thence from B to D along the radius vector CD, a distance $BD = NO$. Let $f(\rho, \beta) = 0$, be the equation of the curve MO relatively to the rotating disc; $F(r, \varphi) = 0$, the equation of the path MD relatively to the earth; then will $MCO = d\beta$, $DCM = d\varphi$, $rd\varphi = MB$, $MN = \rho d\beta$; and

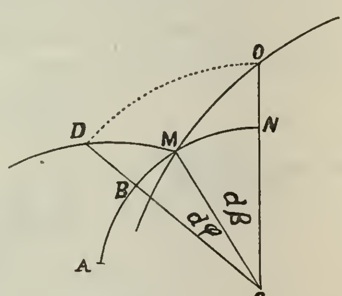


Fig. 4.

$$rd\varphi = \rho\omega dt - \rho d_{,}\beta, \tag{1}$$

$$r = \rho, \text{ since } CO = CD, \tag{2}$$

$$\therefore dr = d\rho, \tag{3}$$

from theory of curves, $$ds^2 = \rho^2 d_{,}\beta^2 + d\rho^2, \tag{4}$$

from eq. (n), $$ds^2 = \omega^2 (\rho^2 - r_1^2 + c_r^2) dt^2, \tag{5}$$

where r_1 and $\omega^2 c_r^2$ are the constants of integration corresponding to r_1 and c_1 in equation (o). These equations combined with the equation of the curve of the tube, $f(\rho_{,,}\beta) = 0$, will, by elimination, give

$$\varphi = \int \psi (r)\, dr,$$

which integrated will give the required locus. If the tube be radial, we have $\beta = 0$, and equations (4) and (3) give

$$ds = d\rho = dr,$$

which combined with equation (5) gives

$$\omega t = \int \frac{dr}{\sqrt{r^2 - r_1^2 + c_r^2}}$$

$$= \log. \left[\frac{r + \sqrt{r^2 - r_1^2 + c_r^2}}{r_1 + c_r} \right],$$

since $t = 0$ for $r = r_1$. Transforming,

$$r = \tfrac{1}{2} r_1 (e^{\omega t} + e^{-\omega t}) + \tfrac{1}{2} c_r (e^{\omega t} - e^{-\omega t}),$$

which is the required equation. If r_1 and c_r are both zero, r will be zero for all values of t.

The exact path, however, is of little importance compared with the relative directions of entering and quitting the wheel.

The change in the actual energy of the particle depends upon the initial and terminal actual velocities. Thus if w_1 be the initial *actual* velocity and w_2 the terminal *actual* velocity, then will the change in *actual* energy be

$$\tfrac{1}{2} m (w_2^2 - w_1^2). \tag{q}$$

It appears from equation (o) that the angular velocity of the particle is not involved in the change of *relative* energy; hence, this effect will be the same whether the path be straight and radial from r_1 to r_2, or straight and inclined between those points, or a spiral passing several times around the centre between circumferences whose radii are

r_1 and r_2; or finally, if it passes without and within those circumferences having only their initial and terminal points at distances r_1 and r_2 from the axis.

Therefore, Mr. Frizell, in the last August number of this JOURNAL, page 94, erred when he said "ω represents the angular velocity of the body *M*," for it represents the angular velocity of the disc or tube; but is correct in saying "This movement is partly angular and partly radial. The angular element of this motion must be added to or subtracted from the angular motion of the disc to find the true angular velocity of the body *M* on which the centrifugal force depends." But he errs in assuming, as the close of the last extract seems to imply, that "the centrifugal force" is sought; when, in fact, it is the *energy* gained or lost *relatively to the tube* due to the action of the tube on the body, and not even the *actual* energy.

The distinction between force, relative energy, and actual energy, should be kept in mind. He also errs, if we understand him correctly, in assuming (p. 95) that "the above expressions would be true if the body *M* had merely a radial movement on the revolving disc," for here, as in other cases, equation (o) applies only to the motion along and relatively to the path, and hence, in this case, to the radial velocity. Thus, to illustrate, take a more simple case, that of a particle starting at the axis with no finite initial velocity and moving along a radial arm, then equation (o) gives

$$c_2 = v_2.$$

which is the *radial* velocity with which the body will quit the tube; but since it also has the circular velocity v_2 the *actual* velocity with which it quits the arm, will be

$$\sqrt{v_2^2 + v_2^2} = v_2\sqrt{2}.$$

Referring now to the works quoted by Mr. Frizell, "Weisbach, 'Hydraulics and Hydraulic Motors,' by Prof. Dubois, introduction, page xliii" (quoted also, J. F. I., p. 94), the author errs where he states, "If, then, a body moves in a rigid path or groove, which revolves about a fixed axis, the *vis viva* of the body is increased or diminished by the product of the mass and the difference of the squares of the velocities (v_2^2 and v_1^2)," etc.; unless it be understood that the *vis viva* referred to is that *relatively to the tube.* The relative energy may be increasing while the actual energy is decreasing.

The same author errs, page xliv, where he states, "The work which the body is capable of performing before coming to rest is

$$W = \frac{c_2^2 - c_1^2}{2g} G = \frac{V_2^2 - V_1^2}{2g} G;" \qquad (r)$$

for this is neither the actual nor the relative energy of the body; but simply the relative energy gained or lost, the destruction of which would simply restore the relative initial energy. The expression bears no known relation to the actual energy; and, hence, the text appears to establish the correct equation upon an erroneous basis.

In the "Mechanics of Engineering," Coxe's translation, the author appears to err, page 611, where he states, "We have the centrifugal force of the body

$$P = \omega^2 Mz,"$$

unless the author means that ω is the angular velocity of the particle, which is nowhere stated, but, on the contrary, it is stated in the notation of that author that "ω is the angular velocity of the top," meaning *tube*, as we are using it.

The expression, however, may be so explained as to be consistent. The object of the analysis is to find the velocity relatively to the disc. According to the principle of D'Alembert the force which accelerates a body's motion is exactly equal but opposite to that which would maintain equilibrium, and is such that if the body be at rest, the equal opposite force would prevent motion. A particle will be at rest relatively to a uniformly rotating disc if it have the same circular velocity as the disc and about the same axis, and is also acted upon by a constant force directed towards the centre of motion just sufficient to keep it in a circular arc. The uniform angular velocity will be maintained with no expenditure of force, and the latter condition may be secured by a string attached to the body and the axis of rotation, the tension of which will equal the centrifugal force of the body, $M\omega^2 z$. This is the centripetal force of the string upon the body, and equals the centrifugal force of the body upon the axis of rotation. If, now, motion is to be along a fixed tube on the disc, resolve the centripetal force (assuming that the motion is to be away from the centre) normally and tangentially to the path; these components, substituted for the string, will also keep the particle at rest *relatively to the tube*. The normal component, though it exists after the string is severed, can produce no motion *relatively to the tube;* but the tangential component,

after the string is severed, will produce motion along the tube, the circumstances of which may be determined by Newton's second law. Weisbach, however, determines the velocity according to the principles of energy. Thus, if $M\omega^2 z$ be the force in the direction of the radius z, the energy produced by working from radius r_1 to r_2 will be

$$M\omega^2 \int_{r_1}^{r_2} z dz = \frac{1}{2} M\omega^2 (r_2^2 - r_1^2) = \frac{1}{2} M (v_2^2 - v_1^2).$$

That author also errs, page 612, where he states that "The energy stored by the body in describing the path AMB, supposing no other force to act upon the body will be," our equation (r); unless it is understood to mean *energy relative to the tube.* This is the more worthy of note, because the language is substantially the same as that given at the bottom of the same page, although the latter necessarily refers to *actual energy.*

These views and references are all in accordance with those given, possibly first, by M. Poncelet in his historic solution of the Fourneyron turbine (*Comptes Rendus,* 1838, p. 269), where he says "The equation of the relative movement in the interior of the wheel, having regard to the action of the centrifugal force which develops, per second, a quantity of work

$$\tfrac{1}{2} M (v_1^2 - v^2);"$$

where v_1 is the velocity of the inner rim and v that of the outer rim; which expression is the same in value as that given by Rankine. It is well to note that this author correctly refers to the *relative* movement, and to the work done, and not merely to "balance *centrifugal force*" as Rankine, though with questionable accuracy, has stated. Rankine's expression is, at best, merely suggestive of the source of the analysis, but not descriptive of it.

If a single particle passed through a tube free to rotate, doing no external work, the angular velocity of the tube might, and generally would, constantly vary; for while the energy of the particle was being imparted to the tube, the velocity of the latter would increase, and *vice versa.* If there be a continuous flow of particles, work may be done at a constant rate, and thus the condition of those turbines in which the water enters and flows as a free jet, be realized. In turbines of the Fourneyron type there is usually a pressure, either positive or negative, at the inner rim of the wheel.

In the wheel discussed by Rankine the effect of reversing the direc-

tion of flow of water relatively to the vane may be found by considering the initial circular velocity as v and the terminal as zero, then will the entire energy lost to the water and imparted to the wheel from this cause be

$$\tfrac{1}{2}mv^2 - \tfrac{1}{2}m.0^2 = \tfrac{1}{2}ma^2r^2,$$

which is at once the sum of the heads due to the centrifugal action and reversed relative velocity of flow, as given by our author, page 195, when $v = ar$ as it should in his analysis; and this added to the kinetic energy of the water flowing into the wheel, which is $\tfrac{1}{2}mv^2$, gives mv^2, as before.

Or, in accordance with a better philosophy, this wheel, run at this speed, may be analyzed by considering that the radial flow passes directly through the wheel and its energy lost, while the tangential velocity (or velocity of whirl) is gradually and fully destroyed in the wheel; its entire energy having been imparted to the wheel, and hence the case is similar to that of a jet flowing tangentially into a hemispherical vane moving in the same direction as the jet with one-half its velocity; in which case the pressure against the vane in the direction of motion is known to be mv; hence in the wheel the work per second will be

$$mv.ra = mv^2$$

as before.

It is interesting to trace the velocities of the water in the wheel. The initial velocity along the vane will be

$$v \tan. a,$$

and the terminal velocity

$$nv \sec. \beta;$$

hence, by the aid of equation (c), we have

$$\frac{nv \sec. \beta}{v \tan. a} = \operatorname{cosec.} \beta;$$

hence the velocity *relatively to the vane* at exit will be cosec. β times that at entrance; and, practically, may be, say, 3, 4, or 5 times that velocity; but *relatively to the earth* it will, at entrance, be comparatively greater and quit with a much smaller one.

This, however, is not the case with all turbines; for if the water enters the wheel as a free jet it will pass along the vane with a uniform velocity *relatively to the vane*, and hence the radial velocity, or velocity

of flow, will be variable, being greatest where the tangent to the curve of the vane coincides with the radius of the wheel at that point, and diminishing beyond. In this case the cross section of the stream must be uniform, and the velocity with which the water issues from the gates will be that due the total head. The velocity of the wheel and the conditions for maximum efficiency for this case may easily be shown graphically. Thus, let FE, tangent to the guide plate CE, represent the velocity with which the water issues into the wheel at E. Let AE represent the velocity of the inner rim of the wheel, and joining A and F, FA will represent the velocity in magnitude and direction of the water *relatively to the float* EGH, and hence the first element of the float, or that at E should have the direction of FA when correctly found. The water will pass around the curve EGH with a uniform velocity of FA *relatively to the float*, the passages having a uniform cross section, and quit the wheel with the relative velocity $HI = FA$. The velocity of the outer rim will be

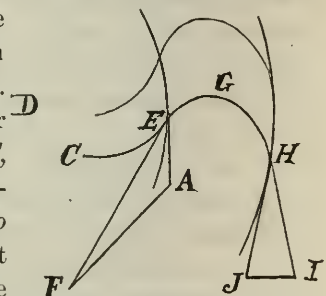


FIG. 5.

$$JH = n.AE,$$

where n is the ratio of the second radius to that of the first; and hence JI will be the actual velocity with which the water quits the wheel. If JI, as thus found, be parallel to the radius of the wheel DH, passing through H, the best conditions will have been secured; but otherwise, assume a new value for AE and repeat the operation until JI has the required direction; then will the resulting direction of FA be the proper direction of the first element of the float EG, and AE the velocity of the inner rim of the wheel for best effect, and JI the velocity lost. The efficiency will be

$$\frac{FE^2 - JI^2}{FE^2}$$

But this analysis is applicable only when the *relative* velocity along the vane is uniform. To secure this velocity and at the same time have the wheel passages full, the depth must vary from E to H inversely as the normal width between the consecutive vanes, making the developed vertical section of a vane similar to Fig. 6; which form is similar to

Boyden's diffusor, though the functions of the two are quite different. This illustrates why Rankine restricted his analysis to the case of full wheel-passages; for otherwise the action would have been that of a free jet instead of a stream so confined as to have a uniform radial velocity.

That the direction of flow of the water at exit should be radial for best effect, regardless of the construction of the wheel, may easily be shown. According to equation (q) w^2 should be as small as possible.

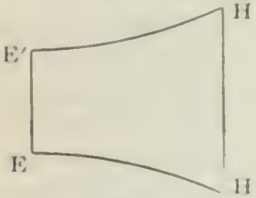


Fig. 6.

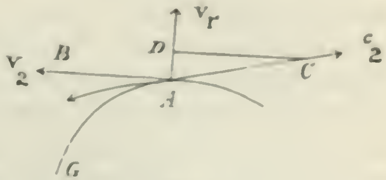


Fig. 7.

Let $AC = c_2 =$ the velocity of exit relatively to the vane AG. $AB = v_2$, the velocity of the wheel relatively to the earth. Take $AC = c_2$, and CD, parallel to $AB = v_2$ and join A and D; then will AD in magnitude and direction represent the actual velocity of discharge $= w_2$; and

$$w_2^2 = c_2^2 + v_2^2 + c_2 v_2 \cos. CAB.$$

Considering CAB and c_2 or v_2 as constant, we find w_2 a minimum for $v_2 = c_2 \cos. C$; which makes AD perpendicular to CD or to AB; one of the conditions assigned by Rankine. If now CAB be the variable, w_2 will be zero for $CAB = 180°$, in which case c_2 will be equal and opposite to v_2.

March 20, 1884.

Polynesian Hieroglyphs.—Abbé J. Bund has published a lithographic reproduction of a photograph, which was made, under the direction of the Archbishop of Tahiti, from a hieroglyphic tablet. The original was given to Father Zumbohm, on Easter Island, or, as the natives call it, Rapanui. The characters are engraved on a piece of wood, about 35 centimetres long and 30 wide (13·78 × 11·81 inches), by means of sharp stones. Some of them present resemblances to fishes, birds, men, and animals, while others seem to be merely fanciful. The repetition of similar characters, and the orderly arrangement, are such as to indicate an alphabetic meaning.—*Les Mondes*, March 15, 1884. C.

THE ELLIPTICITY OF PLANETS.

By L. d'Auria.

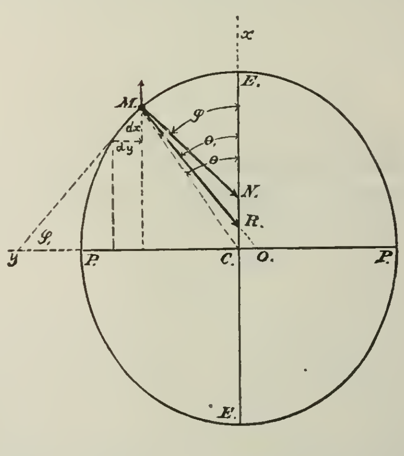
Admitting that planets were originally in a fluid state, however heterogeneous their respective masses may be considered, their form of equilibrium when fluid, must have been such that the direction of the resultant of all the forces acting upon any point of the free surface must have been normal to the surface itself. Now, the form of equilibrium of any fluid mass when at rest is the sphere, and when any fluid sphere is made to revolve around any one of its diameters, it becomes more or less flattened on its axis of rotation on account of centrifugal force. This causes the sphere to become an oblate ellipsoid, whose minor diameter coincides with the axis of rotation itself; and, therefore, the equation of any meridian line on the surface of any fluid mass revolving around an axis of inertia can be expressed by

$$a^2y^2 + b^2x^2 = a^2b^2.$$

Differentiating this equation we have

$$\frac{dy}{dx} = -\frac{xb^2}{ya^2};$$

and observing that the first member represents the cotangent of the



latitude φ of a point M, whose co-ordinates are x and y (Fig. 1), and

that $\frac{x}{y}$ represents the cotangent of the latitude θ of the same point referred to the centre of the ellipsoid; we have

$$\frac{\sqrt{1-\sin.^2\varphi}}{\sin.\varphi} = -\frac{b^2}{a^2}\frac{\cos.\theta}{\sin.\theta};$$

and

$$\sin.\varphi = \frac{\sin.\theta}{\sqrt{1-\cos.^2\theta e^2(2-e^2)}},$$

where $e^2 = \frac{a^2-b^2}{a^2}$.

On the other hand, let MR represent the direction and the intensity of the attraction of the whole ellipsoid upon the point M, which attraction we designate by g; and put $MO = \rho$; angle $MRE = \theta_1$; angular velocity $= \omega$. Then, the resultant of the attraction g, and the centrifugal force at M, must coincide with the normal MN, for centrifugal force is parallel to EE; and since this latter force is expressed by $\omega^2\rho \cos.\theta_1$, we have for the resultant itself,

$$f = g\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)};$$

and, therefore,

$$\sin.\varphi : \sin.\theta_1 = g : g\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)};$$

$$\sin.\varphi = \frac{\sin.\theta_1}{\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)}}.$$

Comparing this value of sin. φ with the preceding one, we find

$$e^2(2-e^2) = \text{tg.}\,\theta\,\text{cotg.}\,\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right) + \frac{\sin.^2\theta_1 - \sin.^2\theta}{\sin.^2\theta_1\cos.^2\theta}.$$

When θ and θ_1 become equal to each other, that is, when the point M is considered very near to the equator of the ellipsoid, then

$$\frac{\sin.^2\theta_1-\sin.^2\theta}{\sin.^2\theta_1\cos.^2\theta} = o;\ \text{tg.}\,\theta\,\text{cotg.}\,\theta_1 = 1;\ \rho = a;$$

and

$$e^2(2-e^2) = \frac{\omega^2 a}{g}\left(2-\frac{\omega^2 a}{g}\right);$$

$$e^2 = \frac{\omega^2 a}{g}.$$

Since the ellipticity is expressed by $\varepsilon = \frac{a - b}{a}$; we have

$$2\varepsilon - \varepsilon^2 = \frac{\omega^2 a}{g}; \; [a]$$

and neglecting ε^2, we have, approximately,

$$\varepsilon = \frac{\omega^2 a}{2g}.$$

Now in the case of our planet,

$$\omega = \frac{2\pi}{86184}; \; a = 6377278 \text{ meters}; \; g = 9 \text{ meters } 81462;$$

(including centrifugal force). Hence,

$$\varepsilon = \frac{1}{578}.$$

This value is entirely too small compared with $\frac{1}{300}$ as deduced from geodetical measurement of arcs of meridians and parallels; but the discrepancy cannot be ascribed to incorrectness of equation [a], since the latter has been deduced from a well established mathematical principle. It may be due partly to the fact that since the time the earth became compact enough to retain its form, its volume has been considerably contracted uniformly all around, which evidently increases its ellipticity; and partly to a retardation of the earth's axial rotation since that time, which also increases the value of ε, by increasing ω, in equation [a]. Both these causes, however, are based upon the assumption that our planet must have lost its fluidity long ago, although in its interior it may be yet intensely hot; and since there is no other way to account for the discrepancy in question, we must recognize in this an excellent confirmation of the opinion lately advanced by Sir William Thomson on the constitution of the earth as regards the observed phenomena of precession, nutation, and tides.

That the earth's axial rotation is subject to a certain retardation, has been almost evidently shown by astronomers in order to account for the apparent acceleration in the moon's orbital motion; and such retardation has been estimated at about ten seconds in a century.

The ellipticity of the planet Jupiter, computed approximately after the formula

$$\varepsilon = \frac{\omega^2 a}{2g},$$

is found to be $\frac{1}{24}$, while, according to observations, it should be about

$\frac{1}{17}$. The discrepancy here, which is due to the same causes above explained, is much less than in the case of the earth, and this seems to show that if at present the planet Jupiter is not perfectly fluid throughout, it is yielding enough to obey in a certain measure the forces which tend to decrease its ellipticity, a conclusion which is in perfect accordance with the observed physical conditions of this planet, and otherwise gives strength to our assumptions.

TO CHICAGO IN EIGHTEEN HOURS.

By Robert Grimshaw, M. E.

[Read at the Stated Meeting of the Franklin Institute, April, 1884.]

I have the honor this evening to submit to the Franklin Institute the outlines of a bold, but feasible project for making the regular run between New York or Philadelphia and Chicago, in eighteen hours, with comfort, safety, and cheapness. At present, the transit occupies from 27 to 37 hours, according to the route and the character of the train.

To accomplish the desired result, necessitates changes in engine, train, method, and permanent way.

Naturally, the limits of this paper do not permit me to rehearse all the details of the proposed selections and innovations; but the most important of them will be outlined, as a basis for discussion.

This paper is the outcome of a discussion started by me in the *American Journal of Railway Appliances* in December last; I have no patents to advertise and no axes to grind. Many of the suggestions in this paper are mine, others have been contributed by eminent mechanics, practically familiar with the building, repairing and running of high speed locomotives. I do not, however, propose to designate which are mine and which are not, having been much amused by hearing ideas, contributed or indorsed by leading builders and master mechanics, and some of which have been for some time in successful operation, characterized as impracticable and visionary. All I will say in this connection is, that whatever any of my hearers may consider as good and practical, no matter what it is, I do not claim. For anything which any one may consider particularly good for nothing, or old, or wild, or unfeasible, or idiotic, I accept full responsibility. I am perfectly aware that this

will result in my at once fathering and disclaiming all those ideas about which among my hearers there may be diametrically opposed opinions; but the inconsistency will be not mine, but that of the audience.

For such work, the engine needs, in a high degree, steaming capacity and economy of fuel, cylinder power and economy of steam, tractive power, adaptability of wheel base to the curves necessarily encountered, proper equalization and distribution of weight, prompt and safe control by throttle, reverse lever, and brake, exemption from tendency to leave the rails, particularly on curves and at switches; freedom from jerking, swaying, "wee-wahing," and hammering, and good behavior as regards spark throwing and heating of wearing surfaces.

This is, perhaps, asking a good deal in an engine; but the higher the standard and requirement, the better the attainment; and in all the points named, existing engines can be bettered.

Steaming capacity and economy call for good fuel and water, and proper draft, large grate and heating surfaces properly disposed, the grate kept properly covered and fire clean, water heated and purified before feeding; heating surfaces kept free from scale and sludge on one side, and soot and ashes on the other.

Cylinder power and economy demand high initial and mean effective pressures and low terminal and back pressures. This must be got by large port area without excessive passage clearance, and a better valve motion than the present shifting-link abortion, with its attendant throttling, wire drawing, exhaust choking, and lop-sided distribution.

To get high tractive power, the drivers must have as much weight upon them as the rails, joints and bridges will stand. There is no use in an engine being more than able to slip her drivers on up grades and with maximum train load, on icy rails.

We must distribute our reforms among the framing, running gear proper, fire box and appurtenances, boiler proper, stack, valves and steam passages, and valve-gear.

Perhaps, the necessity for simultaneous reform in so many elements may result in a hybrid type of engine; but it must be remembered that many hybrids are useful; one of them, the much maligned mule, is an indispensable factor in civilization.

For framing, I should select the bar type as perhaps the best understood by American builders, and best adapted to the permanent

way of the next decade. But it requires marked reform from the usual manner of making up. It needs to be stiffer vertically, to be better braced diagonally in a vertical plane, and freer from short, sudden changes in direction, and from welding flaws. It should be of mild steel, die-forged by pressure, as by hydraulic or steam toggle-presses, instead of anvil-forged by hammer blows. The angles should be well reinforced; and the whole frame considered as a truss subjected in its various parts to certain constant and known weight stresses, plus other intermittent racking, twisting and pounding strains. I trust that master mechanics and locomotive builders will pardon me for saying that the services of a good bridge engineer could be employed with

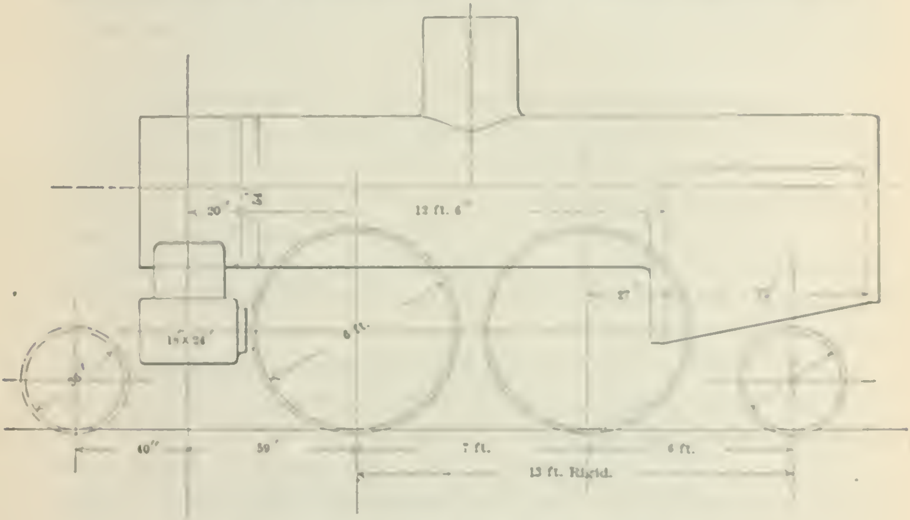


FIG. 1.—PROPOSED WHEEL DISTRIBUTION.

advantage in re-designing the framing of high speed American passenger engines.

I would propose for each horizontal member of the bar-frame, a beam rolled of ⊥ section, with considerable depth of web; jaws of same section, but with considerable re-inforce welded in the framing angles.

For wheel distribution, I propose two pairs of drivers, a "pony" or single pair leading truck, and a pony trailing truck.

Objection has been made that pony leaders are dangerous, and that a four-wheeled truck is necessary for safety. In reply to this, English fast engines have even rigid leaders, and often lead with the

drivers. I know of no instance where a locomotive has been derailed, owing to the pony truck, where the pony truck has been equalized with the front driving wheels.

A four-wheeled leading truck would increase the length of boiler and flues, and the dead weight of boiler and running gear, and not increase the traction.

Proposed diameter of drivers is 72″, placed 84″ between centres; of leading truck wheels 36″, 99″ in advance of leading driver centres; of trailing truck wheels 36″, 72″ back of rear driver centres.

The trailing truck may be rigid, giving 13 ft. rigid wheel base and total wheel base of $21\frac{1}{4}$ ft. Or the trailing wheels may be on a swinging bolster pony truck if necessary, which would make the rigid wheel base only 7 ft. The proposed wheel base distribution may be seen in the diagram, (Fig. 1.)

Two pairs of drivers are chosen because, although single pairs do the best work in England, they are harder on the permanent way and cannot climb away so well from a station if the grade is anything to speak of and the rails are slippery.

All engine wheel centres to be press-forged of mild steel, with hard and tough steel tires 1″ greater diameter than the centres; the interstitial ring being hemp packed by steam or hydraulic pressure to absorb shocks and vibrations.

Centres and tires of all wheels to be given a running balance while turning on a cock-head, and the completed wheels to be similarly balanced when put together.

Particular attention to be paid to counterbalancing reciprocating parts, and the balance attained to be such as to lessen vertical irregularities rather than fore and aft pulls.

The flanges of all wheels in the train are to be of extra depth and thickness, and those of the front drivers to be lubricated by grease-blocks as on Austrian railways, to lessen flange friction and wear of rails and flanges.

Rear drivers to be either flangeless, or with extra play in the wheels, in case the trailing pony does not have a swing motion.

Axles to be of mild steel with $10\frac{1}{2}$″ x 8″ journals in phosphor bronze or equivalent bearings. Journals to be formed by pressing a ground hard steel sleeve over a mild steel center and then forcing on the wheel.

Power brakes to be applied on both sides of each driver, so as to

give increased friction and prevent strain and wear on axle boxes, and on brasses of main and side rods.

As regards the brake, I make the following quotation from the *American Journal of Railway Appliances:*

"An important requisite is suitable and adequate *brake power.* This is of the first importance for safety, convenience and expedition. *First*—As already intimated, the power brake for such a train must be easily graded. For slow-ups, through centres of population, around curves and down grades, a brake is needed which will not go off like a cannon—using all its power when but part is required—but one which may be applied to just the extent which the engineer may desire, and no more. And this grading in brake power must be attainable without any mechanical change in the equipment other than that which may be effected instantaneously in the cab. *Second.* The needed brake must indicate accurately to the engineer, at any moment, the amount of brake power he has, not only on his engine, but also on his train. *Third.* It must be a brake which will at once give notice of any damage to any part of the train, without, necessarily, bringing it to a halt in a dangerous place. Or, in other words, the brake must apply automatically in case of damage, to remain set, or be instantaneously released, at the will of the engineer. *Fourth.* The brake equipment should be so devised that even a considerable damage to it will not disable the brake. *Fifth.* The efficiency of the brake should not be affected by sudden changes in temperature. *Sixth.* It should be free from liability to trouble from lack of equalization in the power applied to separate cars. *Seventh.* The brake power should be adequate, instantaneous in its application and release, and available at all times, in whole or in part. *Eighth.* It should be cheap, and as cheaply maintained as is consistent with the highest degree of efficiency and safety. *Ninth.* Above all, it should be free from any liability to creep on and *stall trains.*"

Springs to be in two parts, separated vertically by an open space and a central distance piece, so as to give by this open trussing greater strength for a given weight of metal.

In the matter of fuel, there are four classes to choose from: (1) lump coal, (2) "briquettes," or blocks of artificial fuel made from screened anthracite or bituminous slack, mixed in suitable proportions, and compressed by hydraulic machinery; (3) water gas, made in fixed plants at terminal and other stations, and compressed to fifteen or

twenty atmospheres in cylindrical mild steel tender tanks, or reservoirs; and (4) petroleum, vaporized or sprayed at the moment of burning, and at the varying rates required for the constantly varying work to be performed.

The artificial fuel of briquettes has the advantage of cheapness and compactness and of regularity in firing. Either compressed water-gas, or petroleum would give lightness of tender, and regularity and rapid and absolute controllability of evaporation, together with great capacity and high duty.

For the present we shall consider the engine to be designed for lump coal, or for "briquettes" of compressed coal slack.

Boiler to be of $\frac{7}{16}''$ mild steel, 56″ outside diameter, straight top made with only one longitudinal seam, and that on top; holes either drilled, or punched scant and reamed to size; hydraulic riveted and concave caulked; manhole to come in the dome and be reinforced with a mild steel ring.

I would prefer to do without the longitudinal seam by having the rings rolled seamless, or to do away with the girth seams by making the entire shell of one sheet, but at present neither of these plans can be carried out.

Distance from centre of front sheet to centre of stacks 20″. Crown sheet 27″ back of rear driver centres.

Thickness of dome $\frac{3}{8}''$; of extended smoke box $\frac{5}{16}''$, of smoke box $\frac{1}{2}''$. Height from top of rail to centre of boiler 7′ 3″.

235 basic steel tubes, each 12′ 6″ long between tube sheets, and 2″ outside diameter.

Objection might be made to the great length of tube, but they are only a foot or so longer than usual, and need give no trouble as regards tightness. This gives an external heating surface of tubes of 1,537 square feet, and a fire area through tubes, less ferrules, of 3·92 sq. ft.

Fire box 120″ long and 52″ wide, inside. Height of crown sheet above top of grate, at centre, 52″. Material of inside fire box copper, $\frac{1}{2}''$ thick at sides and front, $\frac{7}{8}''$ at back and $\frac{1}{2}''$ in crown.

Radial stays, forked at the crown sheet end.

Heating surface of fire box, 84 sq. ft., making a total heating surface of 1621 square feet.

Exhaust nozzle, if discharging into stack, $3'' \times 3\frac{1}{2}''$ instead of $2\frac{1}{2}'' \times 3\frac{1}{2}''$, as is usual for $18'' \times 24''$ cylinders.

Duplicate sets of try cocks and glass water column, and regularly renewable fusible plugs, kept free from scale.

The fire box may be corrugated to give increased strength and surface, and permit of expansion and contraction without causing leaks.

If coal or briquettes are used, there will be a spring fire door, operated by the stoker's foot; a deflecting plate inside the fire door; a perforated bridge-wall; and arrangements for admitting either steam or heated air at will through the bridge-wall, or in the side walls, or in the closed ash-pan, which latter will have an air-tight "slat dump." The grate bars would be mostly water tubes, and there would be rocking sections for cleaning. There would be a live steam-blower in the stack.

Smoke box to be of the "extended" class, with spark arrester.

Experiments with the extended smoke-box on the Eastern Railroad show that "the engine will make steam with her exhaust tips from ⅛ to ¼ inch larger in diameter, with the extension" than without; that it gives 15 per cent. minimum fuel saving; lessens smoke, and "throws whatever sparks do come through so high that they are extinguished before reaching the ground."

The fire-box to be supplied with two-part doors, operated by a treadle. There should be a brick arch on insulating water-tubes. The water-legs to have vertical deflecting or circulation plates, to cause rapid currents down the outside and up the inside.

The pressure carried should be not less than 160 gauge-pounds; and, in fact, the enforced loss of fifteen pounds pressure per square inch in all non-condensing engines, even where the back pressure is clear down to the atmosphere (which it never is in any locomotive, much less in one to run at high piston speeds), should point to a still higher initial pressure, say 180 to 200 pounds.

There should be extra thick non-conducting lagging, by reason of the higher temperature (372° F.) of steam at 160 pounds.

The dry-pipe and throttle should be extra large, and there should be a superheating pipe. There should be two injectors, each of a capacity four times the evaporative requirements.

There may, perhaps, be a "blow-back valve," discharging the escape from the safety valve into the tender, for the treble purpose of quieting the noise, economizing fuel, and lessening the damage done the sheets by injection of cold feed.

The blast to be supplemented by controllable jets of superheated live steam introduced at the front and sides of the fire-box.

Cylinders, as before stated, to be 18″ x 24″.

If a D valve be used, which is not recommended, it should be of the Allen type, with 6″ travel; the upper line of the steam edges to be worked to a quarter circle, to assist in the flow of steam.

The steam chests, if a D valve be used, to be on the sides of the cylinders; or else spring relief or shifting valves to be supplied, to lessen danger from water working over.

Steam ports for D valve, instead of $1\frac{1}{2}''$ x 16″, as is usual, to be $1\frac{1}{2}''$ x 20″ at the valve seat, with passages tapering down to $1\frac{1}{2}''$ x $16\frac{3}{4}''$ at the counter bore. This is to give 25 per cent. more area with a given port opening, than is usual for steam admission at early cut-offs; giving with $1\frac{1}{5}''$ width of port uncovered, an effective open port

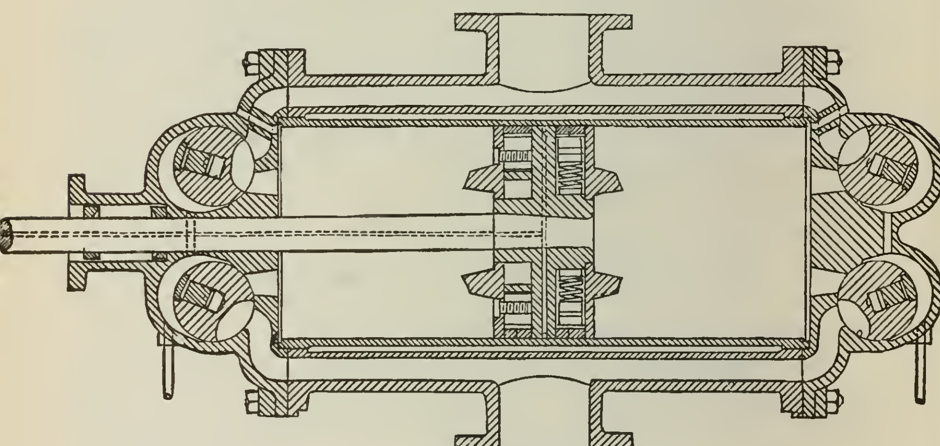


Fig. 2.—SUGGESTED VALVE AND PISTON ARRANGEMENT.

area of $1\frac{1}{5}'' \times 20'' = 24$ sq. in. at the valve seat; the maximum admission area at the counter bore being only $1\frac{1}{2}'' \times 16\frac{3}{4}'' = 25\frac{1}{8}$ sq. in. even when the port is fully uncovered.

Valve gear to be of the Joy or other radial type; preferably of such construction as to give full port opening in $\frac{1}{8}$ of its travel, stay open during the next $\frac{3}{4}$, and close during the final $\frac{1}{8}$ travel; lead and cushion to be equalized, rather than cut-off and release; and the valve gear to be so proportioned and adjusted as to do its best work at that point of cut-off most used.

On no account should any type of a link motion be used. Preferably, the steam distribution to be by four cylindrical valves across the

heads, having reciprocating partial rotation; running in oil under steam pressure, taking steam under the lip; hung on hardened steel trunnions, bearing on hardened steel bushes; motion from the crosshead. (Fig. 2.)

Piston to be spring packed with rings scarfed by a cut halfway through the width of ring, then round the ring 3″; then the other halfway through, so that as the ring wears the sides of the circumferential cuts always touch.

Piston to be lubricated by oil passing from a cup on the crosshead, through a central drill hole in the piston rod, to the centre of the top of the piston head. (Fig. 2.)

Piston rods and valve rods to be steel, and metal-packed by a spring-

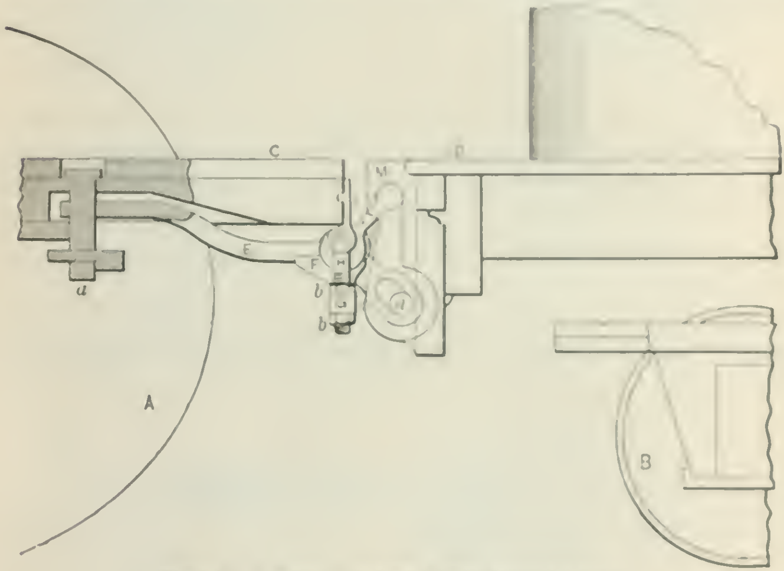


FIG. 3.—AUTOMATIC TRACTION INCREASER.

packed collar fast to the rod, and playing steam tight, though without binding, in a bored cylindrical box.

[As an alternate, Babbitt-bushed stuffing boxes, 4 rod diameters in length, bored $\frac{1}{1000}$″ larger than the rods.]

Crosshead to be of steel, of the vertical type, with adjustable phosphor bronze shoes playing on two cast iron guides of diamond section. Wrist pin, fast in the rod and playing in two bronze-bushed bearings, one at each end, in the crosshead.

Preferably, all the journals to be formed by forcing a hardened steel sleeve over a mild steel centre. All pins and cylindrical journals to be turned and ground on centres. Crank pins to be oiled by graduating cups with spring-valves which give down a fixed charge of graphited oil at each stroke and will not run dry when the crank is on centres.

Parallel and main rods rectangular section; the connecting rod largest at the crank-pin end. The parallel rods would have solid

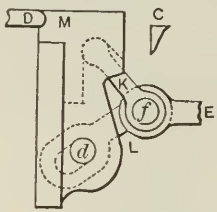


FIG. 4.

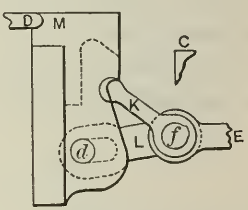


FIG. 5.

ends, and brass bushes pressed in. While this arrangement costs a little more at first, a bush fits the pin better than keyed brasses. Solid ends for rods have the advantages that a careless engineer cannot key up so as to injure the rods; there are no keys to become loose and no bolts to clear.

Connecting rods taking hold outside of the wrist-pins have been objected to by Westerners as causing undue spread of cylinders and

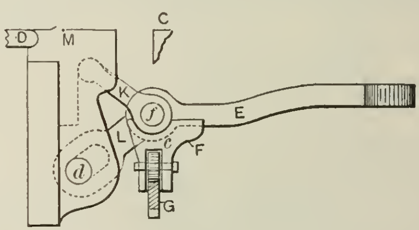


FIG. 6.

hence causing swaying. These objectors do not perhaps know that all Pennsylvania Railroad passenger engines are built with the rods taking hold of the wrist pins and give no trouble on this score. The sand box could go well down against the wheel case, as in British engines. Increase of traction on grades and curves is not to be got by sand alone, perhaps not at all by sand, but by an automatic traction increaser

capable of putting a maximum of 10 to 15 tons extra weight on the drivers, from the tender. (See Figs. 3 to 6.)

The connection between engine and tender should not be rigid, as on curves this causes the flanges of the forward engine truck and of the rear tender truck to crowd the outside rail, and the drivers and the forward tender truck to crowd the inner rail, unless the tender-truck axles are radial; which they ought to be in any case.

For the heavier curves and grades, the regular hauling engine is to be supplemented by a six coupled "bank engine," which will lie with full steam up, on a siding a few miles in advance of the tough place. The instant the train passes the siding, the bank engine starts out to catch it and gradually increasing its speed until slightly greater than that of the train, it catches the rear of the last car, which is supplied with extra strong buffer springs, and the bank is taken with the aid of the extra engine.

Main headlight to be electrical (receiving current from a dynamo direct driven by a pony engine), and supplemented by a side lighting oil headlight above it; both lamps swiveling sidewise by a lever from the cab.

Weight of engine ready for service 96,000 lbs., of which from 48,000 up to 64,000 lbs. may be equally divided between axles by a shifting fulcrum, and the rest, 48,000 down to 32,000 lbs, equally divided between the leading and trailing ponies.

The piston area of each cylinder is 254·5 square inches; displacement, 6,108 cubic inches; the driver circumference 18·85 feet, or 226 inches.

Putting on the drivers $\frac{2}{3}$ of the total weight of 48 net tons, we have, as the cylinder capacity to move the engine one inch, $32 \times 5 = 160$ cubic inches, or $160 \times 226 = 36{,}160$ cubic inches per revolution; giving $36{,}160 \div 4 = 9{,}040$ cubic inches piston displacement required per revolution.

This calls for $9{,}040 \div 254·5 = 35·5''$ stroke for $18''$ piston diameter, or $9{,}040 \div 24 = 376·67$ sq. in. piston area for $24''$ stroke. This requires $\sqrt{\dfrac{376·67}{0·7854}} = 21·89''$ cylinder diameter, with $24''$ stroke, with the 32 tons on drivers.

If only half the total weight, or 24 net tons, were put on drivers, there would be required 6,780 cubic inches piston displacement in each

cylinder, and this we might put either 18 × 26·6 inches or 18·25 × 24 inches.

We may, then, assume that cylinders 18 × 24 require only 48,000 pounds on drivers.

Tender frame and body of steel, carried on light 33″ steel-tired wheels. Capacity of tank, 3,000 gallons; of coal-box, 15,000 lbs. Weight of tender, empty, 20,000 lbs.;* loaded, 59,000 lbs. Fitted with water-scoop.

Tender wheels "independent," or else axles capable of assuming radial positions on curves. (Fig. 7.)

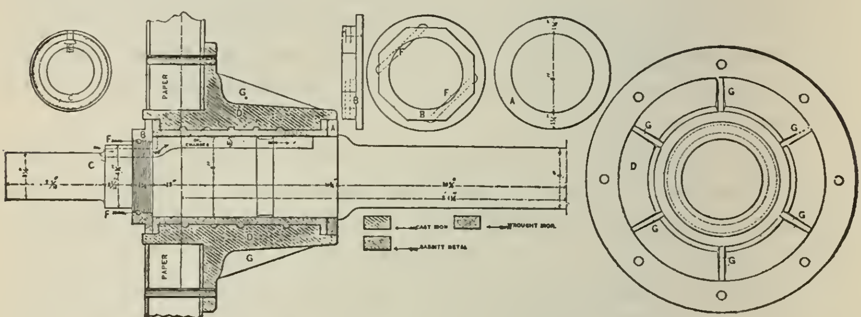


FIG. 7.—INDEPENDENT PAPER CENTERED WHEELS.

Connections between tender and forward car should be by a coupling similar to that between cars; thus making a continuous pull, without the usual jerk when the slack back of the tender is tautened.

The maximum tractive power of the 18 x 24 engine with 72″ driver is $\frac{18^2 \times 24}{72} = 108$ pounds for each pound of mean effective pressure upon the pistons.

912 miles in 18 hours is 50·67 miles per hour including stoppages. Allowing two hours for delays and stoppages, it is just 57 miles per hour while running; and counting loss from five slow-ups and startings, it makes it necessary to make 60 miles an hour right along when at full speed on levels. While this cannot be held on up-grades, dashes can be made down-grades, to keep up the average of 60 miles.

The line of the Pennsylvania Railroad proper, between Philadelphia and Pittsburg, runs (as per official figures, by the courtesy of

* This weight is about 8,000 lbs. less than most estimates, but is based upon a peculiar proposed construction.

Mr. Charles E. Pugh, General Manager), as follows: Starting at Philadelphia, and assuming as the datum line the ordinary high tide in the Schuylkill River, the gradients in feet per mile, the distances in miles, and the heights above the datum line, are respectively:

STATIONS. GOING WEST.	DISTANCES.		HEIGHTS.			GRADES.		
	Bet.	Total	Betw. Sta. +	Betw. Sta. —	Total	Av. ft. per mile.	Worst grades over 25 ft. Length	Worst grades over 25 ft. Ft. per mile.
Broad Street		0			54			
Rosemont	10	10	354	—	408	35.4	1	46
Malvern	10	20	151	—	559	15.1	2.75	49
Downingtown	12	32	—	280	279	23.3		
Parkesburg	13	45	271	—	550	20.8	6	56
Gap	7	52	22	—	572	3.14	7.8	41
Lancaster	18	70	—	200	372	11.11	2.1	23
Mt. Joy	10	80	7	—	379	0.70	1.8	30
Conewago	10	90	33	—	412	3.3	0.6	43
Harrisburg	15	105		100	312	7.25	—	—
Petersburg	105	210	359	—	671	3.41	9.5	20
Barre	2	212	46	—	717	23	0.1	25
Bell's Mills	18	230	336	—	1053	18.66	—	—
Altoona	8	238	118	—	1171	14.75	—	—
Gallitzin	12	250	983	—	2154	81.92	0.3	100
Bolivar	45	295	—	1128	1026	25.07	2.4	80
St. Clair	15	310	40	—	1066	2.66	—	—
Radebaugh	15	325	75	—	1141	5.00	1	35
Turtle Creek	15	340	—	400	741	26.67	—	—
Homewood	8	348	172	—	913	21.50	0.20	50
Pittsburg	6	354	—	178	735	29.67	—	—
	354	—	2970	2286				
Philada. to Pittsburg	354		684			1.93	—	100

It will be seen that in the total distance between Philadelphia and Pittsburg, there is a rise of 684 feet; the highest point on the line, Gallitzin, being 2,100 feet above Philadelphia. The average gradient is only 1·93 feet per mile; but the worst grade is 100 feet, for 0·3 miles of the distance between Altoona and Gallitzin.

The following table gives the distances taken up by rising grades

(going West), from 20 to 30 feet per mile, from 30 to 40, etc. These distances are measured from an official profile, to a scale of 10 miles per inch :

Up-grades, going West.	Miles.
Over 20, and under 30 feet per mile	49·
" 30 " 40 " "	20·1
" 40 " 50 " "	11·4
" 50 " 60 " "	5·5
" 60 " 70 " "	0·
" 70 " 80 " "	0·
" 80 " 90 " "	1·2
" 90 " 100 " "	5·6
100 feet per mile	0·3
	93·1

"At first I was met with more sneers than encouragement, when I broached the subject of engines to make the transits of 900 to 950 miles in eighteen hours, including stoppages. Then master mechanics and locomotive builders, looking at the thing soberly and acknowledging the defects of existing types of engines, announced their entire ability to produce engines which would be able to do the work, month in and month out, on some ideal road—on which the grades, curves, optices and ballast were adapted to the somewhat severe requirements. But it was gravely announced that no such track existed, and that the chances were that no such track could be laid down at any price.

"Next, the concession was made that such a track could be put down, but that it wouldn't pay.

"It having been brought to the mind of objectors to the project, that such track was already down in England and did pay, the ball was tossed over again to the engine; and it was gravely (though anonymously) asserted, in a semi-practical journal, that existing engines had all they could do to knock out thirty-five miles an hour. Up steps an English engineer with figures to prove that in the London and Northwestern, freight trains, sandwiched in between fast through passenger trains, knock out forty-two miles an hour between London and Liverpool; and at present the discouragement seems to be principally

aimed at the permanent way, with a slight digression in reference to the insane Ohio laws about stopping at all grade crossings."

"The question of permanent way should be discussed from first alignment to ballast-tamping, to find out if it is not perfectly feasible and profitable to lay and maintain a track which will stand all the racket to be imposed upon it by any respectable fast train."

The matter of curves and grades requires special attention. Existing practice, particularly in the direction of curves, is particularly unpractical.

"Next comes the question of material, length, weight and section of rail; mode of splicing; ties, ballast and tamping; frogs and switches; and, lastly, bridges. As regards rail material, I suppose that it is about settled that all iron rails are to be things of the past; and that whatever metals are put down, from this point on, for any road of importance, will be of steel of some kind or another. If the advocates of iron rails have anything to say in their favor, or to the detriment of steel rails as at present used, on the ground of economy, durability and safety, I am willing to hear them; but, so far as I am concerned, we are, at present, in favor of steel. Whether it be Bessemer or Siemens-Martin, or some other present or yet unmade kind, I leave out of the question for the present.

"When it comes to lengths, it seems as though the mechanical difficulties of making and handling longer rails, even of the heaviest sections, were rapidly disappearing; and if the majority of the rails laid were in lengths of sixty feet and upwards, we would obviate the expense and risk, attendant upon the use of a great many splices. Even the most rabid advocate of patent rail joints must admit, when you get him down to it, that the best joint is no joint at all; and that the fewer joints there are, even of the most improved type attainable at any price, the less will be the wear and tear of rails, flanges and treads, breakage of springs, cutting of journals and trees, and noise, dust and discomfort to passengers.

I am aware that the question of expansion will be raised, but anticipate this by saying that the present allowance, on a thirty-foot rail, is not so much to cover the expansion as to allow for bad spring of fishplate holes."

Whatever joint is used, however, must be strongly trussed against vertical strains; and this can only be properly accomplished by a stiffening member under the flange.

"As regards sections, consideration of that ought to include both head and flange. There are those who are in favor of perfectly flat treads, and others who call for a gentle curve all the way across. Still others wish right and left hand rails. What the rail head shall be, depends, of course, upon whether the wheel treads are cylindrical or coned; and that is an oft mooted and still undecided subject (not altogether disconnected, by the by, from that of rigid *versus* loose wheels).

"The admirable reports of my friend, Prof. P. H. Dudley, point to the great desirability of increasing the flange width, with a view to lengthening the life and usefulness of wooden cross-ties; and this is well worth looking into, because it means not only cheaper ties in the end, but decreased liability to spreading of track.

"It is very certain that whatever rail section be adopted, it should be such as to comport best with the curve at the base of the wheel flanges.

"I say 'comport best;' and by this wish it very distinctly to be understood, *not* 'correspond with' but 'work well with.' I have serious doubts whether a rail and a wheel which have equal curvatures or correspond like templates, would curve well together. In this I am heretical; but it is not my fault, nor yet a criminal offence.

"Rail weight, of course, depends upon rail material, and upon the weight, frequency, speed and character of the trains passing over the line. The question of material I will assume to be settled; and will also assume that the train will consist of a well-balanced and well-equalized locomotive, having no greater weight than 33,000 pounds per driving axle, rigid wheel base of seven feet six inches maximum, and no greater speed than 350 strokes per minute; hauling a train consisting of tender and five cars, each car weighing with its load, 40,000 pounds, and having this weight distributed upon their three-wheeled trucks, twenty feet between centres. For this, I propose as a starter, a rail section with six inch flange, and giving a weight of seventy-five pounds per yard."

"There is no doubt among master mechanics, road masters, superintendents of rolling stock and master car builders, that there is an undue amount of friction between rail-heads and wheel flanges, at all times, and at all points along the track, but particularly when at high speed and on curves. Neither is there any doubt among passengers that the noise and motion are from this cause greatly increased, and the discomforts of travel thus varied and multiplied.

"It is generally admitted that the principal cause of this roughness of riding and wear and tear of rails and wheel flanges, is the primitive custom of having both wheels pressed fast upon the axle, so that whether or not the wheels upon the opposite ends of an axle are of the same diameter, or of the same 'taper' on the treads, or are round, or are concentric with the axle, or no matter whether the outer wheel on a curve has further to go than the inner, the two wheels are compelled to revolve together.

"It is needless to rehearse in detail the evil effects of this pernicious custom; but it may be useful and interesting to my hearers to present one of the more recent forms of 'loose' or 'independent' wheels, designed to allow the outer wheel when on a curve to revolve more rapidly than the inner, while at the same time preserving a higher degree of safety and not introducing undue cost and complication of parts.

"In the type herewith illustrated, the wheel itself is of the well known 'Allen' construction, with steel tires and compressed paper web or centre, bolted between steel plates, and cast iron hub, or the wheels and axles may rotate as a unit, and of course at the same rate, in the regular outer boxes; or one wheel may revolve with and the other on the axle. Lubrication of the large inner bush and journal is insured by oil passages, *F*, *F*, leading from the oil box to an oil chamber *E*, cut in the journalled wheel seat. The Babbitted bush of the bore is held against end motion by circumfluential ribs, and is flanged up at the ends; the inner flange of each wheel being protected by a wrought iron collar, *A*, butting against the shoulder of the wheel seat, and the outer end having also a wrought iron collar *B*, one and one-half inches long, threaded upon the axle between the outer journal *C*, and the wheel seat journal. These threaded collars *B* are held from turning by pins *F*, *F*, rivetted at each end. The hubs *D*, are each strengthened by six ribs, *G*, *G*, etc."

DISCUSSION.

MR. W. BARNET LEVAN:—Mr. Grimshaw has stated that he proposes to dispense entirely with the link motion. Now, if dispensing with links entirely what will be his position in the event of having to run on a siding or have a break-down. How does he expect to back his engine?

Mr. Grimshaw:—I don't know what is meant by this question. I simply cannot answer it. It assumes that the Joy is not a reversible gear, or is more easily crippled than the link. As a matter of fact the Joy is a reversible gear, and I have no knowledge that it is more easily crippled than the link, owing to the fact that I do not know of any of them having been crippled.

Mr. LeVan:—Where will you find the Joy link motion in use in this country? To my knowledge there are only one or two in use on locomotives, and they are very unsatisfactory.

Mr. Grimshaw:—I have seen letters from master mechanics of several American roads, commending the Joy gear, and stating that they purpose adopting it. I have elsewhere answered the question as to its success on the Reading Railroad, and will only add that Mr. Joy says: "When Mr. Paxson sent me his blue print I saw it would only injure the gear. I told him the centre fixing and overhang would never do. If they *will* make bad designs failure is a matter of course."

Mr. George S. Strong criticised one point on the locomotive. Mr. Grimshaw proposes for fast trains, *i. e.*, the pony, or two-wheel truck as a leading truck, stating that he feared it would not be capable of keeping the rail if detached from the rest of the locomotive, as is a four-wheeled truck, which will keep the rail and forms a truck within itself, at the same time it presents two wheels to take the blow of striking a curve, while the other only presents one. He was afraid that a pony truck for very high speeds would be more liable to break loose from the locomotive and swivel across the track and wreck the whole engine. He also described a locomotive engine with extended smoke-box and other special features, now being built for the Lehigh Valley Railroad Company.

Mr. Grimshaw:—Engineers on the Lehigh Valley Railroad, quoted by Mr. Strong as one on which a two-wheeled truck would not take curves at high speeds, say that they *do* take them, and safely. The Denver and Rio Grande Railroad runs pony truck engines at forty-five miles an hour perfectly safely on their curves. It only requires that the pony wheels be equalized with the front drivers, as now done with perfect success on the Denver and Rio Grande Railroad.

Mr. J. W. Nystrom:—I fully appreciate the importance of Mr. Grimshaw's paper, and believe it feasible to run a train with the high speed he proposes. I would ask that the diagram of the proposed loco-

motive be reproduced on the screen for further remarks on the same. [The diagram was reproduced, and Mr. Nystrom continued.] The greatest difficulty with the locomotive has always been its incomplete combustion, and consequently waste of fuel, by throwing out smoke and sparks, setting fire to houses and other combustibles near the railroad. This evil is caused by an excessive draught through a thick fire on a too small fire-grate. I spoke on this subject at a meeting of the Institute some twenty years ago, and remarked that the locomotive engineers are behind the times in steam engineering.

The principal defect in the locomotive consists in the smallness of its fire-grate, which is confined between the driving-wheels, and it cannot be conveniently increased in length.

In order to overcome this defect, Mr. Wootten placed the fire-grate above the driving-wheels, where there is space enough to make it of the required or proper size. Mr. Wootten's arrangement was illustrated and explained at a meeting of the Institute a few years ago, when I remarked that the fire-grate should be placed over the trailing truck, instead of over the large drivers, which raises the boiler up too high. My suggestion was not considered feasible by some members of the Institute. Now, Mr. Grimshaw produces a sketch of a locomotive with the fire-grate above the truck, but he still confines the width of the grate between the driving-wheels. By moving the boiler back a little, so that the furnace will clear the driving-wheels, the fire-grate can be made wide enough for proper combustion without excessive draught, and thus avoid smoke and sparks, which will result in economy of consumption of fuel.

Mr. Grimshaw proposes to make the fire-grate about 10 feet deep by 4 feet 4 inches wide, making 43 square feet grate surface. It is very difficult to keep a clean and even fire upon a grate 10 feet deep; but if the fire-box is cut off so as to clear the driving-wheels and make the grate 9 feet deep by 7 feet wide, making 63 square feet grate surface; or, perhaps better, to make the grate 8 feet square, or 64 square feet surface, the boiler would be more economical on fuel, and of much greater steaming capacity.

About the cylindrical valves of which Mr. Grimshaw speaks, I would ask if he means piston-valves?

[Mr. Grimshaw produced a drawing of the valves on the screen, to which Mr. Nystrom remarked]: They are Corliss' valves, but Mr. Grimshaw says that he will run the valves in oil under steam pres-

sure, and I cannot see how that can be done without driving the oil into the cylinder.

Mr. Nystrom added: There are many details proposed by Mr. Grimshaw which, whether good or not, have no important bearing on speed of the train which is a function of power, and that additional power can be obtained by proper arrangement of the fire-grate, as before stated.

A small fire-grate requires a stronger draught and thicker fire, which is extravagant of fuel, whilst a larger grate surface requires less draught and a thinner fire, by which the combustion will be more complete. I may refer to a case where I constructed a steamboat with compound engines, and was not allowed to make the fire-grate as large as I desired. After the boat had run about a year the boiler was taken out, and another one with larger fire-grate was substituted, which resulted in better steaming capacity with greater economy of fuel, although the amount of heating surface was the same in both boilers. I cannot see the economy in creating the draught by superheated live steam, instead of by the exhaust, as proposed by Mr. Grimshaw.

Mr. LeVan:—Mr. Grimshaw has stated that a large grate surface is essential for the rapid production of steam for fast running locomotives.

It does not seem to have occurred to them that any boiler may be economical or otherwise, in respect to fuel, according to the rate of evaporation, and that in the case of a locomotive boiler this rate is of necessity almost always varying. For a given rate of evaporation I may have with equally good reason a large fire grate of 58 square feet and a slow rate of combustion, as in the case of the Wootten boilers, as used on the Bound Brook route; or, a small grate, 35 square feet, as in Class "K" Pennsylvania Railroad, and a quicker combustion. In both these cases, from reliable information, the same amount of fuel is burned in the same time and performing the same service. This shows that the same quantity of heat is taken up by the water; consequently, so far as mere economy of fuel is concerned, one boiler will be as good as the other. As for *heating surface,* this has really nothing to do with grate area, but merely with the quantity of fuel burned in a given time. "Heating surface," or rather the fire-box plates or flues, through the substance of which, heat is transmitted, is only effective in proportion to the difference of temperature on the opposite side of the plate.

Numerous experiments and researches have shown that the thickness of the plate has no influence on the coefficient of conduction; thus the thin tubes of tubular boilers transmit no more heat per surface unit than thick plates of a fire-box boiler.

In high speeded locomotives the engines are the greatest drawback. Taking the indicator diagrams of the Wootten and Class "K" engines, you will find the former to show over eight pounds average back pressure before compression commences, while the latter shows but six pounds, when performing the same amount of work and running at the same speed; and the initial steam pressure in the former being 84 pounds, with a boiler pressure of 123 pounds per square inch, and the latter 120 pounds initial, with a boiler pressure of 140 pounds per square inch. The former only realizes 55, and the latter 63 per cent., whereas if they were up to the best stationary practice they should at least show 90 per cent. efficiency.

As regards the Joy valve gear, so far it does not seem to have made much progress in this country. I know of only two in use on locomotives, and they do not seem to give satisfaction; the plan adopted by Mr. Strong is a much better arrangement, as I understand it.

Mr. Grimshaw also says the smoke-box should be of the "extended" class. Now, I maintain, in the first place, that an extension of the smoke box to a length of over say 42 inches from tube-head is essentially and radially wrong and injurious; further, that if the fire-box is of proper size and construction it is *needless*, and if not, it is, as Mr. Parry of the Baldwin Locomotive Works said about the swing trucks "helping to remedy a wrong by making another wrong." It is nothing more or less than a receptacle for unconsumed fuel carried through the tubes, and the claim that it can have any effect whatever (other than a *detrimental* one) on consumption of fuel, evolution of smoke, or steaming qualities of boilers, is, on its face, absurdly false.

No practice was or ever can be successful which runs counter to a well settled theory, and this does violence to the plainest laws governing the movement of fluids, and to their action, as observed in every boiler. We do not put a twelve inch elbow on a six inch water pipe, and if we expand the smoke box of a locomotive to hold sparks, it is impossible, to say the least, that it shall produce any *beneficial* result on combustion, and I claim, as a matter of fact, that it does the reverse.

The experiments with the Shaw locomotive proved this conclusively.

With it she would not give satisfaction; as soon as it was removed and the old arrangement substituted, everything went lovely. The fact is if the deflector plate was removed the result would be quite different. With a deflector and a forty-two inch extension, the results are the same as with a seventy-two inch extension.

It is a notorious fact that locomotives do *not* steam as well after the substitution of the extended smoke stack as before, as I have been repeatedly told by engineers, who thought they could speak the truth without danger of removal. Several of the engineers of the New York West Shore and Buffalo Railroad said that their boilers were steaming poorly from the fact of being handicapped by the late Howard Fry with these abortions, and that it was all they could do to get 90 pounds out of them when they ought to be at least 130 pounds. The majority of engineers on the Pennsylvania railroad will corroborate these statements, when they can do so without risk of losing their positions.

The only logical and common sense plan is the return of the sparks back into the fire-box as done by Pike's system.

Mr. Grimshaw:—I beg to differ diametrically from Mr. LeVan as to the value of large grate surface. Properly managed, and so long as there is sufficient heating surface in flues, large grates give the best economic results. As competitive tests between the Wootten and the Pennsylvania Railroad standard type of locomotives are now (May 12) being conducted, the public will soon have interesting figures in this connection. Grate area of necessity gives larger fire-box heating surface.

Thin tubes give quickness of steaming power in starting, and quick recuperative power after hard pulls on curves and grades.

Private advices from England show the Joy gear to be giving the highest satisfaction on the best roads. The modification thereof, adopted on the Philadelphia and Reading Railroad, was, I understand, protested against by Mr. Joy and its failure predicted.

I took careful advice as to the extended smoke box. It may be "remedying an evil at the wrong end," but sometimes we do not have choice of ends. It is better to remedy an evil at the worst end than to refuse to remedy it because that is not the end we would prefer. The figures on nearly every road where it has been adopted, show saving by its use. The statement that "no practice was ever or could be successful which ran counter to a well settled theory" is too much at variance with the history of progress to need any detailed refutation.

SURVEYS FOR FUTURE WATER SUPPLY.

[From advance proof-sheets of the Report of Col. Wm. Ludlow, Chief Engineer of the Water Department of the City of Philadelphia.]

The increasing pollution of the Schuylkill, whence the main water supply of Philadelphia is derived, and in particular the occasional exacerbation of its unwholesome symptoms to the degree of rendering it totally unsuitable for ordinary purposes, have been already referred to, but the discussion which for a generation has been maintained with more or less earnestness and intelligence, has resulted only in confusing the subject with multiplied and variant suggestions, and in the absence of exact and carefully determined data, could not in the nature of things reach definite conclusions.

Not only has the quality of the water itself been the subject of dispute, but the widest diversity of opinion has been expressed as to the means best adapted to amend existing evils and to make suitable provision for the future.

It seems strange that, in a matter of such vital economic and social importance, this very contrariety of opinion should not have called attention to the one essential point, which had, moreover, been urged by competent advisers, viz.: The necessity for such thorough scientific investigation based upon the actual ascertainment of facts, as should eliminate doubt, and simplify the consideration of the problem by clearly determining its real conditions.

Sooner or later all cities are brought face to face with the water problem, and even when it has been thought that a solution has been reached, the development of industries and the growth of population out-run the provision which it was believed would suffice for long periods, and call for constant watchfulness and care to meet the growing demands.

In the case of Philadelphia, the problem—notwithstanding an apparent simplicity of conditions—is more than ordinarily complex. The Schuylkill brings the water to the heart of the city, and even furnishes the power with which to pump it, and it was therefore natural and proper enough to regard it as the main reliance. But the valley of the Schuylkill has peculiar features. At its source, the water—to a large extent the drainage of the coal measures—is charged with the acids resulting from the decomposition of the iron pyrites, and this

excess of acid is still further increased by the great development of the mining industries. Farther down, the affluents drain a limestone region, and the commingling of the acid and alkali tends to neutralize both and to impart a certain degree of potability to the stream. As was pointed out long since, the water of the Schuylkill is an artificial product, depending for its quality upon a nice balance of chemical constituents, the undue preponderance of either of which would injuriously affect its use—the acid by destroying boilers and water-pipes, the lime by causing scale and rendering the water too hard to be acceptable.

This chemical balance has been hitherto sufficiently well maintained to give no great cause for complaint, but the pollution of the stream by the growing population and the industries of the valley, has become a most serious feature.

The Schuylkill is the natural drainage outlet and sewer for the entire region traversed by it, and unless means can be found and applied to effectually cut off or thoroughly neutralize the multiplied sources of pollution, it is hopeless to consider it available in the future for drinking purposes.

To accomplish this, however, both legislative action and costly engineering works will be required, and the discussion of these must be deferred until the investigation now in progeess shall have fully disclosed their character and extent.

Leaving aside the Schuylkill proper, it then remains to consider whether or not one or more of its affluents could be made to meet the necessary requirements. Of these, the Perkiomen alone is of such character as to promise good results, and in consequence the project of impounding the Perkiomen waters and bringing them to Philadelphia by a gravity conduit has heretofore presented itself as a plausible one, and been urged with more or less earnestness. In the absence, however, of such accurate data as must be obtained, it has been impossible to do more than accept estimates and opinions as a basis of argument, and there now appears good reason to believe that in respect of both quantity and quality, the Perkiomen supply would prove deficient.

Should it result that neither the Schuylkill nor its main affluent can be securely relied upon for the future, the Delaware must be considered, and this aspect of the case has hitherto been scarcely more than glanced at. Numerous suggestions have been made, but again the lack of precise and authentic information has crippled investigation and made discussion futile.

The estimated cost of every one of the Delaware projects has been so large as to discourage their consideration, but if the best results are to be attained, the investigation must be made.

For a gravity supply, the Delaware water must be taken somewhere in the vicinity of the Gap, since it is not until that point is reached that the elevation of the stream is sufficient to give the necessary fall. For a supply by pumping to a conduit, points nearer by offer themselves. The Delaware, *too*, has affluents which might be impressed into service, at least to diminish the necessary pumping.

A third possible source is the Upper Lehigh, whose waters in respect both of purity and altitude, present most favorable conditions, although the distance is great and the minimum flow less than is required for a full supply.

The ideal source is one whose swift waters, drained from a wilderness barren of mines or agriculture, and which the laws of nature will effectually guard from defilement by population or industry, can be diverted from the living reservoir of their rocky channel, and through an aqueduct of reasonable length, be delivered to the city receiving basins, as limpid, palatable, and free from contamination as when tumbling freely in their native bed.

Of all the sources available, the Upper Lehigh comes nearest to this standard, and the Upper Delaware,—whose greater flow is ample for all needs,—comes next.

It happens, however, that ideals are rare of attainment, and in the present case, economic considerations intervene to counsel caution, and compel the fullest and most careful investigation before a decision be made, but it cannot be denied that Philadelphia, with all her fortunate conditions, is doubly favored in having at her command, whenever she shall choose to claim it, a superb source of water supply which for generations to come will fulfill every requirement.

In investigating the Delaware project, some unexpected features were developed. It was necessary in running the conduit lines to the Gap, to take advantage of the valley itself to pass the South Mountain, and in doing this, Point Pleasant,—about half-way between Trenton and Easton, and 30 miles from Philadelphia,—was readily seen to be the most advantageous point at which to reach the valley. The conduit line to this point proved to be much more favorable than was anticipated, largely reducing previous estimates, and furthermore, the quality of the water in the Delaware at Point Pleasant was found to

be extremely good,—better, in fact, than that of any of its affluents,—and almost comparable with the water of the Gap.

The conduit line to Point Pleasant intercepts the Pennypack and the Big and Little Neshaminy, and when nearing the Delaware valley taps also the Tohickon. It results from this combination of circumstances that the Delaware project might be considered as terminating temporarily at Point Pleasant, where pumps could lift the Delaware waters to the conduit and send them in to the Wentz Farm and the proposed Cambria Basins at an elevation of 165 feet. Furthermore, the waters of the intercepted affluents could be used to decrease the pumpage, and in fact for the greater part of the year, would, in all probability, furnish the full amount required.

An aqueduct northward from the Wentz Farm Basin would therefore come almost immediately into service by bringing in the supply from the several streams as they were successively reached, and the Point Pleasant Pumping Station would continue to furnish any amount of excellent water while the construction of the conduit should be proceeding towards the Gap.

The unexpected purity of the Point Pleasant water is due to two causes: First, the considerable aeration and consequent purification the Delaware waters are subjected to by flowing swiftly in a natural channel, and over numerous riffs and rapids; and secondly, the partial exclusion of the low water drainage of the Lehigh by means of the canal on the right bank of the Delaware, which absorbs the summer flow of the Lehigh when it is most highly charged with the sewage of Easton, Bethlehem, and other cities in that valley.

The problem of the Future Supply of Philadelphia, therefore, presents itself under three aspects:

First—The practicability, the requisite means, and the cost of redeeming the Schuylkill, and so effectually guarding it against future pollution as would justify the city of Philadelphia in depending upon the use of its waters for domestic and manufacturing purposes.

Second—The determination of the quality and quantity of the waters that can be reliably obtained from the valley of the Perkiomen; and,

Third—The cost and other particulars of the Delaware project—accepting Point Pleasant as a half-way station, and looking to above the Gap for a gravity supply.

As an alternative to this, the excellent suggestion is advanced by

Mr. Hering, of bringing the waters of the Upper Lehigh into the Upper Perkiomen—thereby increasing the quantity and improving the quality of the latter.

It will be seen by any one conversant with the subject, that it has grown to great, and it may be said, unexpected proportions. The area of country to be examined, whether by accurate surveys or reconnoissances, is larger than has ever been attempted in this country; and, in this connection, a comparison of the necessary extent of the Philadelphia surveys with those made by other cities, will be instructive.

New York, with a topographical area to be covered of about 2,000 square miles, of which 100 were mapped and 250 were carefully reconnoitered, has, since 1875, spent an average of over $30,000 annually, or about $250,000.

The Baltimore surveys cost about $15,000, but only the Gunpowder project, which has since been successfully completed, was seriously considered, and the length of the conduit was seven miles only.

In Boston, the areas surveyed were about 50 square miles, and examinations were made of a total of about 5,500 square miles. The length of conduit line was 15¼ miles. The investigation occupied about three years, and cost $60,000.

The Philadelphia investigation will require careful surveys of about 468 square miles, conduit lines about 183 miles, and a general examination of about 6,500 square miles.

The work which has so far been accomplished is excellent in character, large in amount, and economical in cost; and it is of the greatest importance that it should be carried to completion with the parties now fully equipped and trained to their work.

The total expenditure that will be required cannot yet be determined. The investigation, owing to an unexpected balancing of various advantages and disadvantages, physical and economic, has assumed proportions that were not at any time heretofore contemplated. But it is work that is absolutely essential to an accurate and reliable solution of the problem, and I feel no hesitation in saying, that whatever necessary expenditures are incurred will be amply repaid in the end.

The expense of maintaining and supervising the work is about $2,500 per month, and this year will probably see the greater part of the field work fairly advanced to completion.

The results are too important, and the consequences of a failure to

obtain all necessary information would be too serious to allow me to feel any hesitation in asking for such funds as may be required to complete the investigation.

The reports from Dr. Leeds and Mr. Hering furnish a full account of the operations under their respective directions, and contain information of the greatest interest and value.

The Department was especially fortunate in securing the services of these two gentlemen, both of whom are well known in the professional world in their respective branches of inquiry and have evinced the highest interest in the important labors entrusted to them.

The circumstances are such as to necessitate a continuance of the investigation in order to cover the entire field, and to reach such reliable results as shall justify the preparation by the Department of final estimates and recommendations; but the conditions are now thoroughly understood, many points of doubt have been eliminated, and the work can proceed with clear conceptions towards a determinate conclusion.

The varying character of the several streams at the different seasons makes it necessary to establish minimum as well as average data, and observations extending over at least a brief term of years are required.

Analysis has so far confirmed opinions formed from engineering and physical data, and Dr. Leeds is enabled to reach the preliminary conclusions expressed in his final remarks, viz.: as to the advisability of ceasing to pump water at the Kensington Station, and as to the necessity for immediate measures to guard the Schuylkill from pollution, if its use as a source of supply is to continue. Inasmuch as any modifications of the existing system must, under the most favorable circumstances, require for their completion a period depending upon the means which can be made available for this purpose, the conclusion of Dr. Leeds as to the frequent and recurring non-potability of the Schuylkill, call for most serious consideration on the part of those upon whom is laid the responsibility of making adequate provision for the necessities of this great city.

Mr. Hering's report contains a careful *resumé* of all publications upon the questions of future supply, and gives a detailed account of the work of the surveying parties.

The plan of operations was laid down after a careful preliminary examination of the subject, and from time to time fresh or modified instructions were given as the work extended.

Great care was exercised in selecting the gentlemen to conduct the field work, and the results are such as to reflect high credit upon all engaged.

It is believed that the greater part of the field work of the survey can be completed before the close of this year, and the entire investigation concluded at a total cost not much in excess of the expenditure made by Boston, to cover an area of very much less extent.

Analysis of Spectral Rays.—Cornu has published the result of his investigations upon the *a* group of spectral lines, which was discovered by Brewster and is situated between *C* and *D*. Its great increase of intensity when the sun approaches the horizon indicates its telluric origin; but it is not due to the vapor of water. Cornu finds that it contains lines of three different kinds: 1. Metallic lines of solar origin, recognizable by their oscillation. These lines are gray, broad, and blurred upon the borders, while the telluric rays are black and sharp; 2. Dry, atmospheric lines, forming two unequal series of channelled double rays. This group reproduces, line for line, the arrangements of the telluric groups *A* and *B*, so that the three groups should be attributed to the same element, which is probably oxygen. M. Egoroff finds that the reciprocals of the wave lengths of the homologous rays, in the three groups, are nearly in arithmetical progression; 3. A third group is formed by lines which have a considerable intensity when the sun is near the horizon, and which disappear almost entirely when the atmosphere is cold and dry. The grouping of lines in harmonic ratio, noticed by M. Egoroff, was first published by Chase, on August 23, 1877 (Proc. Am. Phil. Soc., xvii, 109).—*Chron. Indust.*, Feb. 24, 1884. C.

New Paint.—At the military port of Brest, a mixture of zinc white with zinc chloride has been used for some time, with good result, in painting wood and metals. It becomes very hard, and can be washed or brushed without injury. It should not be applied, however, in rainy or frosty weather, as it then becomes mealy and scales off easily. Chloride of zinc is not the only salt which possesses the property of forming a mastic by its mixture with zinc white. Sorel long ago indicated the proto-chlorides of iron, manganese, nickel and cobalt as good bases for mastic. After having verified his views, the authorities of Brest

have extended his experiments, and have shown that the sulphate and nitrate of zinc, the sulphate, nitrate and chloride of iron, and the sulphate and nitrate of manganese form good mastics and paints with zinc white.—*Chron. Industr.*, March 2, 1884. C.

Parchment-Paper Packings.—A German mechanic engineer observed that damp parchment-paper, when strongly compressed, forms a homogeneous and unctuous material, which has great rigidity and toughness. Finding, moreover, that when exposed by its cut edges to the friction of a smooth metallic surface it undergoes but an insignificant amount of wear, he took out a patent for the manufacture of journal boxes from compressed parchment-paper. One great advantage of the material consists in the lubrification which can be produced by water alone; a light greasing with oil at the outset would be sufficient to prevent rust.—*Les Mondes*, March 8, 1884. C.

Underground Telegraph Wires.—The bulletin of the French Telephonic Society calls attention to a complete interruption on most of the telegraphic lines, for 48 hours, caused by a violent tempest. The subterranean wires which united Paris with the principal cities of Northern and Eastern France worked, however, without interruption, so as not only to satisfy all their normal traffic, but also to supply much of the deficiency arising from the failure of the other lines. Had it not been for the underground wires, Paris would have been entirely cut off from all telegraphic communication with other points.—*Les Mondes*, Feb. 23, 1884. C.

Calling Dogs by Telephone.—In December, 1877, during some of the earliest experiments with telephones in France, one experimenter held a receiver near the ear of a dog, while another, who was in a distant room, called the dog by name several times. At each call the animal turned in surprise and assumed a most comical look of amazement. A similar occurrence, in New York, has been mentioned in some of the journals. A lost dog, having a receiver placed near his ear, recognized the call of his master, and replied by joyous barkings and licking the apparatus, from which he seemed to expect to see his master come forth.—*Les Mondes*, Feb. 23, 1884. C.

Ancient Metallic Architecture.—Charles Normand, the architect who restored the Vendome column, has read a paper before the

French Engineering Society, upon the employment of metallic architecture before the Christian era. He presents evidence of its use, not only in the details of public and private edifices, but also in the erection of buildings in which nearly the entire structure was of metal. Columns of iron and bronze were used in many of the Assyrian and Jewish monuments, and some metallic beams of the Roman Pantheon were remaining in the sixteenth century. Metallic joists and terra-cotta panels were used in ceilings, in the same way as in many modern structures.—*Chron. Industr.*, March 9, 1884. C.

Modern European Flint Weapons.—Two tumuli have lately been explored in Piat, Côtes du Nord. In the smaller there was a medal, with a portrait of Maximian, who shared the throne with Diocletian from 284 A. D. to 305 A. D. It was placed under a flat stone, which was evidently designed for its protection. Near it was an urn of graceful outline, containing bones and ashes. In the other tumulus, the explorers found a sword, a number of daggers, one of which was ornamented with golden studs, and about fifty flint arrows. It appears, therefore, that flint was employed, together with metal, as late as the third century of the Christian era.—*Les Mondes*, Feb. 16, 1884. C.

Sinking Shafts in Quicksands.—M. Haton de la Goupillière read a paper before the French Société d'Encouragement, upon the Poetsch method of sinking shafts in watery soils and quicksands. A series of hollow iron tubes, with cutting sabots, is sunk in a circle around the well. Within these, other smaller tubes, pierced with numerous holes, are placed. Through the inner tubes a refrigerating liquid is forced, in a continuous current, until the soil in the critical neighborhood is frozen, and the intrusion of the sand and water is prevented so as to allow the sinking of the main tubular shaft.—*Chron. Industr.*, March 16, 1884. C.

Crab-Apple Hedges.—A skillful French horticulturist writes to the *Gazette des Campagnes*, that nothing is more suitable for a living hedge, more vigorous, or of a more rapid growth, than the wild crab-apple. Two-year old stocks should be set out, either in autumn or in spring; a good spring ploughing enlivens the growth and checks the weeds. A second ploughing, in the month of August, is also necessary, and if there is garden mould or manure to be added, so much the better. The young plants should be allowed to grow, without prun-

ing, for two years. In the third year they should be cut down to about 10 centimetres (4 inches) from the ground, and then the shoots will develop in all directions with remarkable vigor, the strongest growing straight upwards, the weakest creeping upon the ground and intertwining, so as to form a barrier, which will be impenetrable even by the smallest animals. When the hedge is once started, it will only be necessary to trim the top to the desired height as often as is needful, and to dig about the roots whenever weeds threaten to exhaust the soil.—*Les Mondes,* March 15, 1884. C.

Electric Equilibrium.—Gore has investigated the degree of force required in an electric current in order to hinder a chemical combination. To show that the chemical and electric forces can be balanced, he takes a solution of silver and of cyanide of potassium and plunges into it two electrodes, one of silver the other of platinum. The silver electrode tends to dissolve, with an energy which depends upon the richness of the cyanide and its temperature. This tendency is counteracted by passing a current through the electrode, the intensity of which is measured by the ordinary methods. When the current arrests all chemical reaction the two forces are in equilibrium. This method, simple as it is and susceptible of a great variety of applications, is very fruitful in results and opens to science a new field for the measurement of chemical forces.—*Les Mondes,* April 21, 1883.

Frontal Electric Photophore.—Messrs. Hélot and Trouvé have presented to the French Academy the description of a medical illuminating apparatus, to which they give the above name. It is composed of an incandescent lamp, enclosed in a metalic cylinder, between a reflector and a converging lens. The apparatus, which is very light, is applied to the forehead, and furnishes an intense glow, the field of which can be varied by a slight displacement of the lens. A battery of bichromate of potash furnishes the electricity. The light can be used for illuminating the natural cavities or a deeply situated field of surgical operation.—*Comptes Rendus,* April 16, 1883.

Explosive Waves.—Berthelot and Vieille have investigated the enormous living force and pressure which are propagated in explosive waves by the change of chemical constitution. They observed in the oxyhydric mixture a velocity of 2,841 metres, while that of the sonorous wave is only 514 metres. With the oxycarbonic mixture the

velocity of the explosive wave is 1,089 metres, while that of the sonorous wave is only 328 metres. The explosion produces a single and characteristic wave; but the sonorous phenomenon is due to a periodic succession of waves. The excess of *vis viva* communicated to the gaseous molecules by the act of chemical combination, represents the precise amount of heat which is set free in the reaction. The explosive wave is propagated uniformly and its velocity is independent of the pressure, as well as of the material and diameter of the tubes, above a certain limit. The velocity constitutes, for each inflammable mixture, a true specific constant, the knowledge of which possesses great interest, in view of the theory of gaseous movements as well as its applications in the use of explosive materials. The conclusions of the research are applicable not only to mixtures of explosive gases but also to solid and liquid explosive systems, provided they are wholly or partially transformed into gas at the moment of explosion.—*Ann. de Chim. et de Phys.*, March, 1883.

Natural Harmonies.—On October 20, 1880, W. de Fonvielle, M. Perron, and Capt. Chayrn made a remarkable balloon ascension in England and heard musical sounds while they were floating, at sunset, at an elevation of several hundred metres above the ground. In a large forest, situated in the West of France, during warm and calm summer days, when the ocean of verdure is the seat of a rapid evaporation, a harmonious sound is often heard in the air, which is well known to the peasants and which they call the "song of the forest." Abbé Gastoin observed that the sonorous vibrations of the æolian harp are not heard when the air is agitated by the wind, but only when it is calm, and harmonic currents are produced by changes of temperature. Tyndall's experiments in radiophony seem to furnish a satisfactory explanation of all these phenomena.—*Rev. Scientif.*, April 21, 1883.

Dilapidation of Bricks.—The destruction of brick walls is generally attributed to the influence of heat, dampness and frost; but according to recent observations the true destroyer appears to be a microscopic organism, and the action produced by temperature is of secondary importance. M. Parize has examined with a microscope, the red dust which is produced by the crumbling of the bricks, and he found that it contained a large quantity of minute living animalcules. The magnifying power of the instrument was 300 diameters.—*L'Ingénieur; Chron. Industr.*, April 22, 1883.

Delauney's Earthquake Predictions.—Perrey, Mallet and Delauney have all made very instructive researches upon earthquakes, availing themselves of records which extend over more than a century, and endeavoring to deduce data for predicting the times of recurrence. Daubrée thinks that the statistical statements are insufficient to justify such prediction. Movements of feeble intensity are felt almost every day, in many parts of the globe. Even if the attention is directed almost exclusively to violent shocks, the data are necessarily incomplete, whatever may be the care and the ability of the observers. Europe does not form one-fiftieth of the surface of the globe; vast parts of other continents may be shaken without our knowledge; and the ocean, which covers three-quarters of the globe, must be subject to frequent and numerous shocks, which are almost always unnoticed. One might as well claim to establish a systematic statement of the meteors which fall annually upon our planet, of which more than ninety-nine per cent. remain unknown to us.—*Comptes Rendus,* Oct. 1, 1883. C.

Cause of Earthquakes.—Daubrée, in discussing the recent earthquakes in Europe and Asia, presents many objections to the theory of falling rocks in internal chasms, and thinks that all the phenomena can be satisfactorily explained by the action of superheated steam. He refers to the well-known craters of explosion, such as Lake Pavin, in Auvergne, where the stratified rocks have been cut sharply through, as if by a punch. The modern experiments with gun-cotton, nitroglycerine, and dynamite, have often shown pressures of more than 6,000 atmospheres, and produced results which could hardly be wrought by the pressure of weights 600,000 times as great as that of the explosives. Superheated steam, when set in movement by such simple mechanism as nature often presents, would account for all the action of earthquakes, their violence, their frequent succession, and their recurrence in the same regions for many centuries. It also explains the predilection of earthquakes for regions where there are numerous faults, especially if the dislocations are recent. Earthquakes appear to be, in many instances, like subterranean volcanic eruptions which are smothered because they find no outlets. The motive power of gases, of which we see the gigantic effects in the solar jets or protuberances, appears also to be considerable enough beneath the surface of our planet to explain all the effects of earthquakes.—*Comptes Rendus,* Oct. 8, 1883. C.

Solar Protuberances.—Faye suggests the great probability that hydrogen, when escaping rapidly into the rare medium which surrounds the photosphere, is at first chilled, on account of its enormous dilatation, and becomes invisible to the spectroscope. Afterwards, under the action of solar radiation, it is reheated in various places, so as to be seen by our instruments. An observer, who should return after a half hour's interval, to contemplate the phenomenon, would find the protuberance wonderfully enlarged, without the hydrogen having been required to traverse enormous spaces in the meanwhile. Father Secchi saw small isolated clouds, forming and growing simultaneously without visible connection with the chromosphere, apparently in the same way as the clouds which are formed in our own atmosphere, from the vapor which already exists in the air, but which is latent and remains invisible, until a local cooling, or a change of pressure, determines its condensation.—*Comptes Rendus*, Oct. 8, 1883. C.

General Law of Congelation of Solvents.—The fact that water congeals at a lower temperature, when it holds saline matter in solution, than when it is pure, was known during the last century. In 1788 Blagden showed that the lowering of the point of congelation was proportional, in many cases, to the quantity of matter dissolved. Subsequently Despretz, Leon Dufour, Rudorff, and de Coppet have verified Blagden's law; and Rudorff has explained various anomalies by the fact that the dissolved salts are some of them anhydrous, while others are hydrates. Prof. Raoult, of Grenoble, has experimented upon various groups of mineral and organic substances, in order to fill the lacunae which have been left by previous investigators, and has arrived at the following conclusions: 1. Every solid, liquid, or gaseous body, when dissolved in a definite liquid compound which is capable of solidification, lowers its point of congelation. 2. In two specimens of any body, the purest is the one which solidifies, or rather, which melts at the highest temperature. 3. The atomic or molecular lowering is sensibly constant for each solvent. 4. In weights of different solvents which are proportional to their atomic weights, the lowering at congelation is independent of the nature, both of the solvent and of the body dissolved.—*Comptes Rendus*, Oct. 15, 1883. C.

Electric Aërostat.—A. and G. Tissandier made their first ascent with their electric balloon, on October 8, 1883. The balloon was 28

metres long, and 9·20 metres in diameter at its centre. It was inflated with hydrogen gas, nearly pure, and having an ascensional force of 1,180 grammes per cubic metre. The weight, including the electric motor and all its accessories, was 704 kilogrammes. When the helix was driven with 180 turns per minute, it yielded a work of 100 kilogrammetres and drove the balloon through the air so as to produce a brisk wind. When the head of the balloon was pointed towards the wind it could be kept immovable, although the wind was blowing at the rate of about eleven kilometres per hour. By the help of the rudder considerable deviations were made, both to the right and to the left of the wind's course.—*Comptes Rendus*, Oct. 15, 1883. C.

Observations on the Pic du Midi.—Thollon and Trepied have made some special observations on the Pic du Midi, preparatory to the proposed establishment of an astronomical observatory. The height is sufficient to reduce the thickness of the atmospheric screen by about one-third, the portion which is left below being the one which contains the greatest amount of mist, vapor and dust. By masking the sun with an elongated screen they were able to see Venus, by the naked eye, when within two degrees of the solar disc. The disc often had a sharpness and steadiness such as they had never observed elsewhere, at Nice, in Italy, in Algeria, or even in Upper Egypt. The solar spectrum often appeared crossed, through its whole length, by a considerable number of fine striæ, some brilliant and others obscure, which they could attribute to nothing else than granulations of the photosphere. The hydrogen lines C and F were not continuous, but formed of distinct fragments, of the same order of magnitude as the intervals of the striæ, showing conclusively that the chromosphere offers a system of granulations analogous to that of the photosphere. The two systems are separated in the spectroscope, one giving a continuous spectrum and the other a spectrum of lines. They are blended and confounded in a telescope or in a photograph. It is well known that there are eight brilliant lines in the chromosphere, visible under ordinary circumstances. On the Pic, during the five days on which observations could be made at a favorable hour, the number of lines was increased to over thirty, in the portion of the spectrum which is comprised between D and F, thus giving results very similar to those which are obtained during a total eclipse.—*Comptes Rendus,* Oct. 15, 1883. C.

Aurora Borealis at Behring Strait.—Nordenskjöld has published his observations of the aurora borealis on the *Vega*, during the winter of 1878–9. They lead him to conclude that even during the years of least auroral intensity, the globe is surrounded by a luminous corona, which is nearly constant, and which may be simple, double, or multiple. While the *Vega* was in its winter quarters the corona was usually at a height of ·03 of the earth's semi-diameter (119 miles), and the centre coincided with a point below the surface and a little north of the magnetic pole. The corona, with a diameter of about ·32 of the earth's radius (1,268 miles), extended in a plane, perpendicular to the radius which passes through its central point, thus indicating that its height above the surface of the globe is everywhere uniform. The outline is nearly circular, with slight oscillations in the diameter of the circle, and even in the position of its centre; but in magnetic storms the changes may be rapid and considerable. After repeated observations with the polariscope, there was a universal conviction that the light had no appreciable polarization. The whole paper is one of the most interesting that has ever been published upon the subject.—*Ann. de Chim. et de Phys.*, Jan., 1884. C.

History of Brass.—Pliny speaks of calamine as being produced in melting furnaces when zinc ores were used. According to Aristotle, the people living in the neighborhood of the Black Sea used calamine in order to give copper a beautiful gold color. The alloy of copper and zinc had no special name among the Romans; it was considered only as a beautifully colored "*aes*." In the middle ages, the Greek name "oreichalkos," or mountain copper, was commonly used. The alchemists of the middle ages believed, like their predecessors, that the copper was simply colored by the calamine. Metallic zinc is first mentioned in the fifteenth century, by Paracelsus, but its relation to brass was not fully understood until a later date. The manufacture of brass was carried on especially in Flanders, Cologne, Nuremberg, Paris and Milan.—*Dingler's Journal*, Oct., 1883. C.

Slow Movements of the Soil.—Daubrée presented to the French Academy, with flattering encomiums, the work of Prof. A. Issel, of Genoa, on the Slow Oscillations of the Ground. Faye examines the question from the standpoint of Geodesy, and thinks the author is too ready to sacrifice the idea which has been sustained by Fourier, Cor-

dier and Elie de Beaumont, of the progressive cooling of the earth. In the beginning, when the planet was in a state of complete fusion, its exterior form, coinciding with its mathematical form, was that of an ellipsoid of revolution, flattened at the poles and turning around its smaller axis. To-day, after the slow oscillations of the soil have acted during millions of years, the globe, crumpled and deformed, presents on one hemisphere an accumulation of emerged continents, and on the other a solid crust, profoundly depressed and covered by water. In spite of these striking deformations and the alteration of the visible contours, the mathematical figure of the earth has remained an almost perfect ellipsoid of revolution, as at the beginning; the globe has not ceased to turn, in a stable manner, around its smaller axis, and the variation of weight from the equator to the poles has not undergone the slightest modification.—*Comptes Rendus*, Oct. 1, 1883. C.

Interpretation of Spectroscopic Phenomena.—Faye rejects, as fabulous, the velocities of 100 or 150 leagues per second, which seem to be indicated, at the sun's surface, by the prodigious rapidity with which the protuberances are formed, and the partial displacements which are observed in the hydrogen lines. Thollon contends, however, that the velocities which are indicated by each of these phenomena are quantities of the same order, and that their maximum value corresponds to the cometary velocities in the same region. Every movement of luminous matter, which approaches us or recedes from us, undoubtedly produces a displacement of spectral lines. No theory indicates, and no fact demonstrates, that any other cause is fitted for producing the same effect. It is, therefore, very natural to consider such displacement as an indication of movement.—*Comptes Rendus*, Oct. 1, 1883. C.

Semi-Incandescent Electric Lamp.—P. Tihon has exhibited to the Lyons Society of Industrial Science, a lamp in which he has sought to combine the intensity of the voltaic arc with the steadiness of the incandescent lamp. When the carbons are brought in contact, the resistance is almost destroyed and the light is fixed, but very feeble. It is, therefore, necessary to preserve the arc, in order to secure intensity, and for steadiness it is also necessary to give the current a solid pathway, instead of abandoning it to the medium of the atmosphere. In order to secure both of these ends, the inventor places a small prism of chalk vertically between two carbons, which are slightly

inclined against it at their upper extremities. The current raises the chalk to a temperature similar to that of the arc itself, and increases the conductibility sufficiently to maintain the arc and avoid sudden extinctions. The incandescence of the chalk cannot vary so rapidly as the current, so that the prism serves as a fly-wheel, absorbing the heat of the arc, transforming it into light by its own incandescence, and distributing the light with great regularity.—*Les Mondes*, September 8, 1883. C.

Applications of the Phonic Wheel.—Du Moncel describes numerous useful applications of the phonic wheel, especially in measurements of time. Various chronographs have been devised for measuring very small intervals of time, which occur between different phases of every phenomenon which one may wish to study. In order to obtain such measurements it is essential to have a perfectly uniform movement on the part of the motor which is called upon to furnish the indications. The phonic wheel resolves this problem precisely and in the most simple manner. M. Lacour says that if we calculate the limit of error which can result from this system of measurement we shall find that it is less than $\frac{1}{250}$ of one per cent. The mode of action of the phonic wheel makes it applicable to clockwork in some cases. In fact, as three systems of apparatus concur in its operation and as these systems can be placed at any desired distance apart, the vibrating apparatus may be arranged under such conditions that the external causes which act upon chronometers will be controlled, and then the counting apparatus which is directed by the phonic wheel will furnish indications rigorously exact, in any convenient place. Since many phonic wheels can be introduced in the same circuit we can have many clocks, with movements which are altogether synchronous. The seconds' hand, or any other which moves still more rapidly, can accomplish its revolution without shock and in a manner which is perfectly regular.—*La Lum. Electrique*, April 21, 1883.

Arsenic in Wines.—A wine merchant, having received complaints of his wines, asked Barthélemy to make an analysis, which resulted in the discovery of considerable quantities of arsenic. Upon inquiry, it was found that the proprietor was in the habit of cleaning his casks with dilute sulphuric acid, which is very apt to contain arsenic. That this was the source of the difficulty was shown by examining the wine in new casks, and finding that it was free from poison.—*Comptes Rendus*, Oct. 1, 1883. C.

Waterproof Clothing.—In order to remedy the inconveniences to which soldiers are exposed in stormy weather, the Belgian government proposes to make their clothing perfectly waterproof. The experiments at Vilvorde have satisfied physicians that cloths, which are prepared with a salt of aluminum, do not hinder cutaneous respiration, and chemical analysis shows that they lose neither their quality nor their color. More than 10,000 yards of cloth, after having been subjected to repeated severe washings and tests of different kinds, preserved their impermeability until the threads were worn completely through. The greatest objection to the process is its cost. A suitable acetate of aluminum is obtained by preparing separate solutions of alum and acetate of lead. When these solutions are mixed the lead is precipitated in the form of a sulphate.—*Les Mondes*, September 1, 1883. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held May* 21, 1884.]

HALL OF THE INSTITUTE, May 21, 1884.

Mr. William P. Tatham, President, in the chair. Present 132 members.

The minutes of the April meeting of the INSTITUTE, of the Board of Managers and of the various standing committees were reported and approved. 16 persons were reported to have been elected to membership at the last meeting of the Board.

The paper for the evening, "To Chicago in Seventeen Hours," by W. Barnet Le Van, in the absence of the author, was read by the Secretary. It was discussed by Messrs. Hugo Bilgram, Cyrus Chambers, Jr., and J. W. Nystrom. The paper with the discussion thereon has been referred to the Committee on Publication.

A description, illustrated with perspective and sectional lantern views, of the Master Crusher and Pulverizing Mill was read for Mr. C. Henry Roney, by the Secretary.

The Secretary's report embraced remarks on the possibility of utilizing certain wasted natural forces, and in connection therewith, an illustration of, and remarks on Captain John Ericcsön's Solar Engine; the present position of the Tehuantepec Ship Railway Project of Capt. Jas. B. Eads; and on the Water Gas Controversy in Massachusetts. The following mechanical inventions were also shown and described. The System of Balancing Machinery devised by the Defiance Machine Works

of Defiance, Ohio, a handsome working model of which was presented to the INSTITUTE by the Company. Diefendorfer's Anti-friction Bearing. A Measuring Machine (four inches capacity) devised by Prof. J. E. Sweet, and manufactured by the Syracuse Twist Drill Company of Syracuse, N. Y. An Automatic Nut for Vehicle Axles, invented by Mr. A. Anderson, of Goltz, Md., and a Nut Lock, invented by Thomas Curry, of Philadelphia.

A photographic view of a series of gun and pistol barrels, which had been burst by firing the same when obstructed by "stuck" bullets, wet sand, mud, etc., was shown on behalf of Mr. William McK. Heath.

Mr. G. M. Eldridge offered the following preamble and resolution, which after some debate were adopted, viz:

"WHEREAS, The forthcoming International Electrical Exhibition of the FRANKLIN INSTITUTE will present a school of instruction in electrical science unparalleled in America; and

"WHEREAS, It is desirable that the youth of this city should have a full enjoyment of the benefits thus offered; therefore,

"*Resolved*, That the Board of Education of the City of Philadelphia be requested to make an order that the scholars at all the grammar schools and high schools, who may desire to visit the Electrical Exhibition, may do so under the charge of their teachers, as a substitute for a school session on days to be fixed by the Board."

Mr. J. W. Nystrom offered some objections to the results of the tests of the model of the Gaffney boiler, as reported at a previous meeting by Mr. S. Lloyd Wiegand.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

Annual Report of the Director of the Drawing School of the Franklin Institute for the Sessions 1882–1883.

The progress of the Drawing School for the year which ends this evening, has been very satisfactory. The methods of instruction have been improved, the facilities increased, and an advance made in every particular. Much of the work done by the pupils will bear a critical examination as to the thought and study involved and as to the execution. The specimens exhibited this evening illustrate the system of instruction. Those from the Junior Mechanical Classes show a thorough course in Plane Geometry, and an introduction to the principles

of Projection. This gives the student a familiarity with the names and forms of the principal lines, shapes and magnitudes, with which he has to deal, teaches him graphical methods of solving problems, impresses upon him the importance of care and accuracy, and, at the same time, initiates him into good form as regards using his implements. These classes have been in charge of Mr. George S. Willits.

The drawings from the Intermediate Mechanical Classes give an idea of the importance we place upon a thorough knowledge of Projections. A careful examination of them will show many intricate problems, which would puzzle the most expert; and, it must be admitted, that a student, who has obtained a clear understanding of them, is well prepared for any difficulties that may occur in actual work. Particular care is taken with this branch of the subject, because it is the fundamental basis of mechanical drawing, and, at the same time, is not properly understood and appreciated by draughtsmen generally. These classes have been in charge of Mr. Carl Barth.

The drawings from the Senior Mechanical Class show the application of the principles learned in the other classes to the making of working drawings of machinery. In this class, some complete machine of an interesting nature and good design is taken as a study, its use, operation and construction explained, and the class is required to make detailed drawings of it, to scale, after the manner of our best draughting offices, special attention being given to accurate measurements, the proper use and distribution of dimension lines and figures, the employment of sections and shade lines, and all the technicalities of mechanical drawing. This class has been in charge of the Director.

In the Architectural Class considerable original work has been done and some designs made which are intended for actual construction. The making of plans and elevations of buildings, and details of interior and ornamental work, are the features of this class, which has been in charge of Mr. Edward S. Paxson.

The drawings from the Free-Hand Class show marked improvement this year. This is due in great measure to the better facilities and to the additions made to the collection of casts. In this class, the student first draws from flat copies graded according to his skill, and afterwards from casts, commencing with simple geometrical figures and advancing up to the human form. This class has been in charge of Mr. Edward S. Paxson.

The following students deserve honorable mention for the interest

they have taken, the regularity of their attendance, and the superiority of their work :

In the Senior Mechanical Class.—Willis H. Groat, John S. Wilson, James G. Davis, Miss E. J. Longstreth, Harry P. Ewen, John Way Atkins, Alphonso E. Kirschner.

In the Intermediate Mechanical Classes.—Hugo L. Hund, M. Uhlmann, James M. Cox, Jr., J. Herbick, V. Forbensen, Frank Zimmermann, Benjamin W. Rees.

In the Junior Mechanical Classes.—A. H. Lea, Joseph Trottman, Miss Mary J. Colwell, Elwood M. Rowand, James C. Biddle, Jr.

In the Architectural Class.—Thomas Shenton, George F. Jackson, James J. Allen.

Drawing from Casts.—Thomas Eagan, A. M. Chandler.

In Free-Hand Drawing.—John Walbold, James Dunn, George Highley, John Dueringer.

The following students, at the close of the Winter Term, received scholarships from the B. H. Bartol Fund, entitling them to free attendance during the Spring Term :

Willis H. Groat, Miss E. J. Longstreth, John Way Atkins, James G. Davis, Charles von Berger, Joseph Edel, Hugo L. Hund, C. W. Regester, J. E. Pugh, William Kinhead, Charles Fleming, E. Kolb.

The following students, having completed a full course of four terms, are awarded certificates to that effect :

In Mechanical Drawing.—Harry P. Ewen, Alphonso E. Kirschner, James T. Baker, M. Morgan, Henry M. Lutz, John F. Abbott, Alphonsus Jones, Frederick Weyman, Isaac C. Mercer, Frederick Kalesse, Otto W. Manz, William Newbigging, Charles A. Eimert.

In Architectural Drawing.—George F. Jackson, James J. Allen, John Dueringer, Frederick O'Neill, William F. Cook.

In Free-Hand Drawing.—Edward A. Miller, Frederick Reutlinger, Charles Fleming, W. H. Pabst.

The following students are awarded Free Scholarships for the next term, beginning September 30, 1884 :

Miss E. J. Longstreth, M. Uhlmann, A. H. Lea, Joseph Trottman, James J. Allen, Thomas Eagan.

They will present themselves to the Actuary at that time and receive their tickets.

WILLIAM H. THORNE,

Director.

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(Concluded from page 399.)

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